U.S. Department of Energy
Hanford Site

20-SGD-0018

NOV 14 2019

Ms. Alexandra K. Smith, Program Manager
Nuclear Waste Program
Washington State Department of Ecology
3100 Port of Benton Boulevard
Richland, Washington 99354

Dear Ms. Smith:

ENGINEERING EVALUATION REPORT FOR THE NONRADIOACTIVE DANGEROUS WASTE LANDFILL GROUNDWATER MONITORING, SGW-60589, REVISION 0

This letter transmits the approved Engineering Evaluation Report for the Nonradioactive Dangerous Waste Landfill Groundwater Monitoring, SGW-60589, Revision 0 to the Washington State Department of Ecology (Ecology).

This report addresses the additional information for groundwater monitoring requested in Ecology's letter 16-NWP-143, Groundwater Engineering Report and Final Status Groundwater Monitoring Plan Requirements for the Integrated Disposal Facility, Nonradioactive Dangerous Waste Landfill, Low Level Burial Grounds Trench 94, and Low Level Burial Grounds "Green Islands" Dangerous Waste Management Units.

If you have any questions, please contact me, or your staff may contact, Mike Cline, of my staff, on (509) 376-6070.

Sincerely,

for

William F. Hamel, Assistant Manager
for the River and Plateau
Richland Operations Office

SGD:RDH

Attachment

cc: See page 2

cc w/attach:
J. Bell, NPT
R. Buck, Wanapum
C. E. Cameron, EPA
L. Contreras, YN
D. R. Einan, EPA
M. Johnson, CTUIR
S. Leckband, HAB
N. M. Menard, Ecology
K. Niles, ODOE
S. N. Schleif, Ecology
Administrative Record (NRDWL)
Environmental Portal

cc w/o attach:
S. G. Austin, CHPRC
S. L. Brasher, MSA
S. W. Davis, MSA
M. H. Doornbos, CHPRC
W. R. Faught, CHPRC
L. K. O'Mara, CHPRC

SGW-60589
Revision 0

Engineering Evaluation Report for the Nonradioactive Dangerous Waste Landfill Groundwater Monitoring

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

CH2MHILL
Plateau Remediation Company

P.O. Box 1600
Richland, Washington 99352

SGW-60589
Revision 0

Engineering Evaluation Report for the Nonradioactive Dangerous Waste Landfill Groundwater Monitoring

Date Published
May 2019

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Plateau Remediation Company
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Richland, Washington 99352

APPROVED
By Janis D. Aardal at 4:03 pm, Jun 11, 2019

Release Approval | Date

U.S. Department of Energy (Owner/Operator) Certification

The following certification statement is provided for SGW-60589, Rev. 0, *Engineering Evaluation Report for the Nonradioactive Dangerous Waste Landfill Groundwater Monitoring*, which serves as permit reference material for the Nonradioactive Dangerous Waste Landfill closure unit permit application, permit WA7890008967, Hanford Facility Dangerous Waste Permit (Site-Wide Permit), Revision 9, Part V, CUG-20, Addendum D, "Groundwater Monitoring."

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Joe Franco for   10/4/19

B. T. Vance   Date
U.S. Department of Energy
Richland Operations Office
Owner/Operator

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CH2M HILL Plateau Remediation Company (Co-Operator) Certification

The following certification statement is provided for SGW-60589, Rev. 0, *Engineering Evaluation Report for the Nonradioactive Dangerous Waste Landfill Groundwater Monitoring*, which serves as permit reference material for the Nonradioactive Dangerous Waste Landfill closure unit permit application, permit WA7890008967, Hanford Facility Dangerous Waste Permit (Site-Wide Permit), Revision 9, Part V, CUG-20, Addendum D, "Groundwater Monitoring."

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

L. T. Blackford
President
CH2M HILL Plateau Remediation Company
Co-Operator

5/29/19
Date

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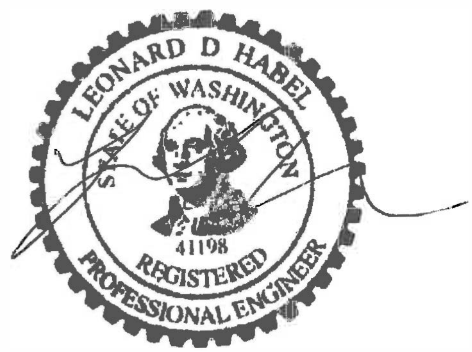
Statement of certification:

I am a licensed Professional Engineer in the State of Washington, No. 41198, with a degree in Environmental Engineering. I have over 26 years of professional experience, including 15 years with groundwater systems. I reviewed the attached engineering study referenced as "Engineering Evaluation Report for the Nonradioactive Dangerous Waste Landfill Groundwater Monitoring, SGW-60589, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington" and I certify that it demonstrates completeness in compliance with WAC 173-303-806(4)(a).

Leonard D. Habel, P.E. Sr. Principal Engineer North Wind Infrastructure and Technology, LLC	April 23, 2019 Date



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Terms

AEA	*Atomic Energy Act of 1954*
API	American Petroleum Institute
CCU	Cold Creek unit
CCU_g	Cold Creek unit gravels
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CPGWM	Central Plateau Groundwater Model
DNAPL	dense nonaqueous-phase liquid
DOE	U.S. Department of Energy
DWMU	dangerous waste management unit
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
HSU	hydrostratigraphic unit
K_d	distribution coefficient
MEUK	multi-event universal kriging
NRDWL	Nonradioactive Dangerous Waste Landfill
OU	operable unit
P2R	Plateau to River (Model)
P&T	pump and treat
PCE	tetrachloroethene
RCRA	*Resource Conservation and Recovery Act of 1976*
Rlm	Ringold Formation lower mud unit
Rtf	Ringold Formation member of Taylor Flat
SWL	Solid Waste Landfill
Tri-Party Agreement	*Hanford Federal Facility Agreement and Consent Order* (Ecology et al., 1989)
TCA	1,1,1-trichloroethane
TCE	trichloroethene

TEDF	Treated Effluent Disposal Facility
TOC	total organic carbon
TRIM	Tikhonov Regularized Inverse Method
VOC	volatile organic compound

1 Introduction

This engineering evaluation report provides information to support the proposed final status groundwater monitoring for the Nonradioactive Dangerous Waste Landfill (NRDWL) based on evaluation of contaminants associated with NRDWL and the expected migration behavior of contaminants in the unit. This evaluation includes results of groundwater flow and particle migration simulations that were performed based on water elevation mapping techniques. NRDWL is an inactive landfill that will be incorporated into Revision 9 of WA7890008967, *Hanford Facility Dangerous Waste Permit (Site-Wide Permit)* (hereinafter referred to as the Hanford Facility Dangerous Waste Permit) as Closure Unit Group 20. This report provides supporting documentation regarding the protection of groundwater required by the *Resource Conservation and Recovery Act of 1976* (RCRA) permitting process for final status facilities.

NRDWL is located southeast of the 200 East Area of the Hanford Site in Washington State and overlies the 200-PO-1 Groundwater Operable Unit (OU) (Figure 1-1). From 1975 to 1988, NRDWL provided for disposal of nonradioactive, dangerous and nondangerous waste generated from process operations, research and development laboratories, maintenance activities, and transportation functions located throughout the Hanford Site. The unit is located directly adjacent to the Solid Waste Landfill (SWL).

This report addresses the additional information for groundwater monitoring requested in Washington State Department of Ecology (Ecology) Letter 16-NWP-143, "Groundwater Engineering Report and Final Status Groundwater Monitoring Plan Requirements for the Integrated Disposal Facility, Nonradioactive Dangerous Waste Landfill, Low Level Burial Grounds Trench 94, and Low Level Burial Grounds "Green Islands" Dangerous Waste Management Units." The letter requests that the U.S. Department of Energy (DOE) develop engineering reports in advance of the complete permit application for the unit groups, with an associated groundwater monitoring plan developed for the final status permit application. The enclosure to the letter requires submittal of an engineering report with the following information included:

1. Information necessary to support the design of the groundwater monitoring well network, such that it is capable of yielding representative samples of groundwater potentially impacted by releases from the dangerous waste management units (DWMUs) resulting from changes in groundwater flow direction, declining water tables, and/or degrading wells that may be causing sample or groundwater contamination.

2. Information supporting design of the groundwater monitoring program that is capable of detecting significant statistical increases in groundwater contamination at the earliest practicable time.

3. Uncertainty in groundwater flow direction so that the appropriate number of wells can be located and drilled. This includes 1 year of background monitoring for WAC 173-303-110(3)(c) and (7), "Dangerous Waste Regulations," "Sampling, Testing Methods, and Analyses," constituents unless previously performed to Ecology's satisfaction. Given the 3-year schedule for drilling and installing new wells, there should be at least 2 years minimum of planning, scheduling, and construction for any new wells or revised groundwater monitoring networks that are approved by Ecology.

4. Descriptions of the approach, input data, any additional information needs, and analysis proposed to evaluate and respond to changes listed in 1. Submit a full report of the complete analysis supporting the proposed approaches, including the methodology and results of validation of any modeling. Modifications of the groundwater monitoring network(s) may be needed to ensure they will continue to yield representative samples of groundwater potentially impacted by releases from DWMUs.

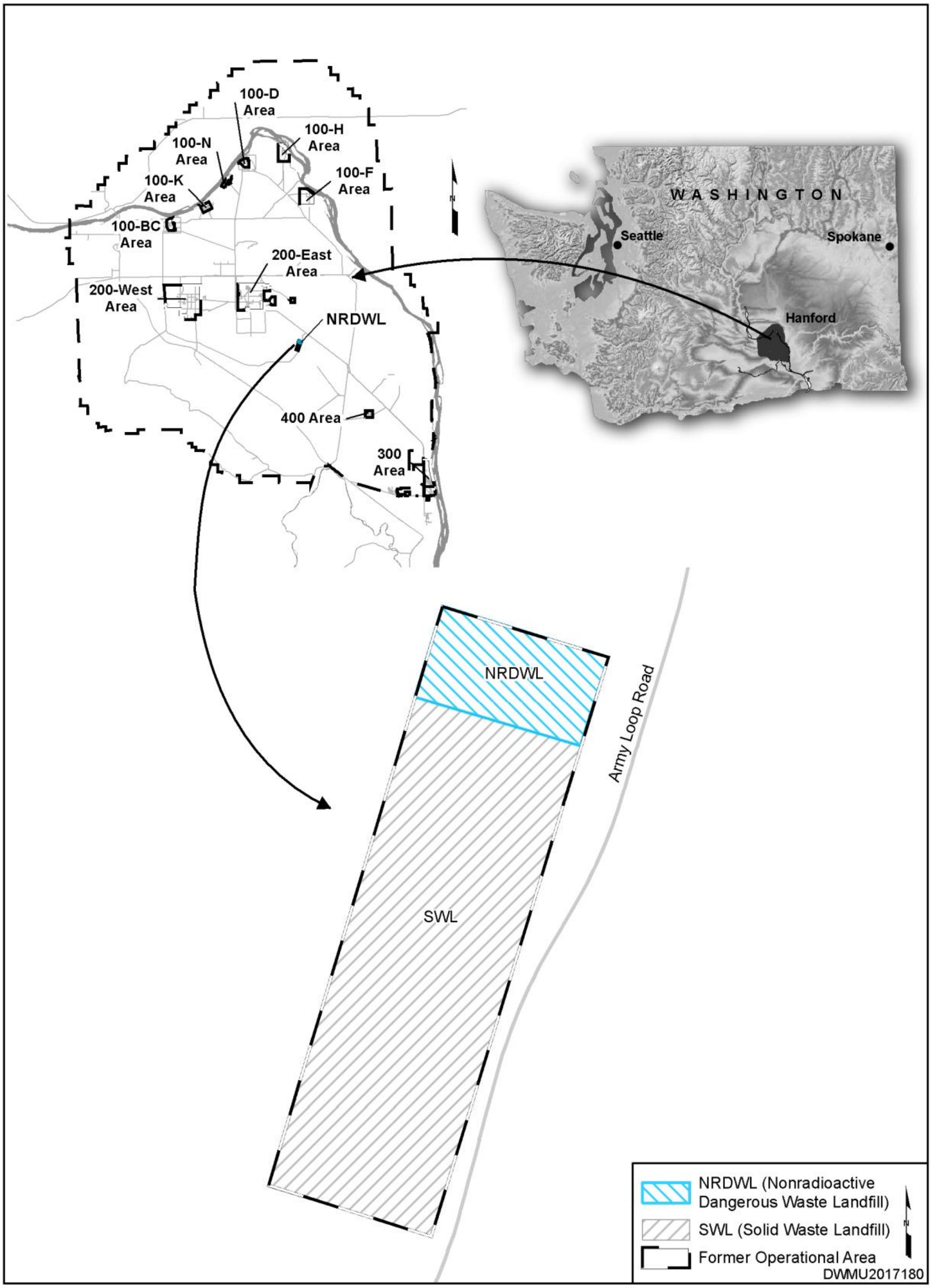

Figure 1-1. Location Map for NRDWL

The analysis documented in this report complies with WAC 173-303-806, "Final Facility Permits," which outlines the contents of the Part B permit application pertinent to the protection of groundwater. WAC 173-303-806(4)(a)(xx)(E) requires the preparation of detailed plans and an engineering report describing the proposed monitoring program to meet the requirements of WAC 173-303-645(8), "Releases from Regulated Units," "General Groundwater Monitoring Requirements." WAC 173-303-645(8) requires a groundwater monitoring system consisting of a sufficient number of wells installed at appropriate locations and depths to yield groundwater samples from the uppermost aquifer. These samples are intended to represent the quality of background groundwater that has not been affected by the leakage from a regulated unit, represent the quality of groundwater passing the point of compliance, and allow for the detection of contamination when dangerous waste constituents have migrated from the DWMU to the uppermost aquifer.

WAC 173-303-806 (4)(a)(xx)(E) specifies that a detailed plan describing the proposed groundwater monitoring program be included in the Part B application with this engineering evaluation report. This engineering evaluation report provides the technical basis for the groundwater monitoring that will be described in that plan. As groundwater monitoring under the detection monitoring program (WAC 173-303-645(9))[1] will be performed along with the general monitoring requirements (WAC 173-303-645(8)), this engineering evaluation report also provides the supporting information for the detection monitoring requirements. When the groundwater monitoring plan associated with this network is incorporated into the Hanford Facility Dangerous Waste Permit, it will replace any other groundwater monitoring plans associated specifically with NRDWL under interim status.

In addition, this report provides information required by WAC 173-303-806(4)(a)(xx)(C) (topographic map), WAC 173-303-806(4)(a)(xx)(A) (summary of interim status groundwater monitoring data), and WAC 173-303-806(4)(a)(xx)(B) (hydrogeological information). Plume maps of any regional contaminants in the area of the regulated unit are also provided.

Applicable groundwater monitoring requirements of WAC 173-303-645 and WAC 173-303-806(4)(a)(xviii) and (xx) are detailed in Table 1-1.

Table 1-1. Pertinent Requirements

Pertinent Requirement	Section Where Requirement is Addressed
WAC 173-303-806(4)(a)(xx)(A) A summary of the groundwater monitoring data obtained during the interim status period under 40 C.F.R. 265.90 through 265.94, where applicable	Appendix A
WAC 173-303-806(4)(a)(xx)(B) Identification of the uppermost aquifer and aquifers hydraulically interconnected beneath the facility property, including groundwater flow direction and rate, and the basis for such identification (that is, the information obtained from hydrogeologic investigations of the facility area)	Section 3.2 Section 3.3

[1] This report presents the information for the scenario where NRDWL enters the permit under a detection monitoring program (WAC 173-303-645(9)). However, since NRDWL is currently under a groundwater quality assessment monitoring program (DOE/RL-2017-19) the scenario where NRDWL enters the permit under a compliance monitoring program (WAC 173-303-645(10)) is also possible.

Table 1-1. Pertinent Requirements

Pertinent Requirement	Section Where Requirement is Addressed
WAC 173-303-806(4)(a)(xx)(C) On the topographic map required under (a)(xviii) of this subsection, a delineation of the waste management area, the property boundary, the proposed "point of compliance" as defined under WAC 173-303-645(6), the proposed location of groundwater monitoring wells as required under WAC 173-303-645(8), and, to the extent possible, the information required in (a)(xx)(B) of this subsection	Appendix B
WAC 173-303-806(4)(a)(xx)(D)[a] A description of any plume of contamination that has entered the groundwater from a regulated unit at the time that the application was submitted that: (I) Delineates the extent of the plume on the topographic map required under (a)(xviii) of this subsection; (II) Identifies the concentration of each constituent throughout the plume or identifies the maximum concentrations of each constituent in the plume.	Appendix C
WAC 173-303-806(4)(a)(xx)(E) Detailed plans and an engineering report describing the proposed groundwater monitoring program to be implemented to meet the requirements of WAC 173-303-645(8)	Chapter 9
WAC 173-303-806(4)(a)(xx)(F) If the presence of dangerous constituents has not been detected in the groundwater at the time of permit application, the owner or operator must submit sufficient information, supporting data, and analyses to establish a detection monitoring program which meets the requirements of WAC 173-303-645(9). This submission must address the following items specified under WAC 173-303-645(9): (I) A proposed list of indicator parameters, waste constituents, or reaction products that can provide a reliable indication of the presence of dangerous constituents in groundwater (II) A proposed groundwater monitoring system	Chapter 9
WAC 173-303-645(2)(a) Owners and operators subject to this section must conduct a monitoring and response program as follows: (iv) In all other cases, the owner or operator must institute a detection monitoring program under subsection (9) of this section.	Chapter 9
WAC 173-303-645(6)(a) The department will specify in the facility permit the point of compliance...at which monitoring must be conducted. The point of compliance is a vertical surface located at the hydraulically downgradient limit of the waste management area that extends down into the uppermost aquifer underlying the regulated units.	Section 9.2

Table 1-1. Pertinent Requirements

Pertinent Requirement	Section Where Requirement is Addressed
WAC 173-303-645(8)(a) The groundwater monitoring system must consist of a sufficient number of wells, installed at appropriate locations and depths to yield groundwater samples from the uppermost aquifer that: (i) Represent the quality of background groundwater that has not been affected by leakage from a regulated unit; (ii) Represent the quality of groundwater passing the point of compliance. (iii) Allow for the detection of contamination when dangerous waste or dangerous constituents have migrated from the waste management area to the uppermost aquifer.	Section 9.3
WAC 173-303-645(8)(c) All monitoring wells must be cased in a manner that maintains the integrity of the monitoring well bore hole. This casing must allow collection of representative groundwater samples. Wells must be constructed in such a manner as to prevent contamination of the samples, the sampled strata, and between aquifers and water bearing strata. Wells must meet the requirements applicable to resource protection wells, which are set forth in chapter WAC 173-160, “Minimum standards for construction and maintenance of wells.”	Section 9.3 Appendix D
WAC 173-303-645(8)(h) The owner or operator will specify one of the following statistical methods to be used in evaluating groundwater monitoring data for each hazardous constituent which, upon approval by the department, will be specified in the unit permit. The statistical test chosen must be conducted separately for each dangerous constituent in each well. Where practical quantification limits (pqls) are used in any of the following statistical procedures to comply with (i)(v) of this subsection, the pql must be proposed by the owner or operator and approved by the department. Use of any of the following statistical methods must be protective of human health and the environment and must comply with the performance standards outlined in (i) of this subsection.	Appendix E
WAC 173-303-645(8)(i) Any statistical method chosen under (h) of this subsection for specification in the unit permit must comply with [standards provided in WAC 173-303-645(8)(i)(i), (ii), (iii), (iv), (v), and (vi)] as appropriate.	Appendix E

Table 1-1. Pertinent Requirements

Pertinent Requirement	Section Where Requirement is Addressed
WAC 173-303-645(9)(a) The owner or operator must monitor for indicator parameters (e.g., pH, specific conductance, total organic carbon (TOC), total organic halogen (TOX), or heavy metals), waste constituents, or reaction products that provide a reliable indication of the presence of dangerous constituents in groundwater. The department will specify the parameters or constituents to be monitored in the facility permit, after considering the following factors: (i) The types, quantities, and concentrations of constituents in wastes managed at the regulated unit; (ii) The mobility, stability, and persistence of waste constituents or their reaction products in the unsaturated zone beneath the waste management area; (iii) The detectability of indicator parameters, waste constituents, and reaction products in groundwater; and (iv) The concentrations or values and coefficients of variation of proposed monitoring parameters or constituents in the groundwater background.	Chapter 8 Chapter 9
WAC 173-303-645(9)(b) The owner or operator must install a groundwater monitoring system at the compliance point, as specified under subsection (6) of this section. The groundwater monitoring system must comply with subsection (8)(a)(ii), (b)[b], and (c) of this section.	Chapter 9

a. WAC 173-303-806(4)(a)(xx)(D) is not applicable because Nonradioactive Dangerous Waste Landfill (NRDWL) has not contaminated the groundwater. However, plume maps of regional contaminants that are in the vicinity of NRDWL (if any) are included in Appendix C.

b. WAC 173-303-645(8)(b) is not applicable because NRDWL is one regulated unit. It is not being monitored as part of a group of regulated units.

Documented releases to the environment have not been identified at NRDWL. Details of the regulatory and groundwater monitoring history can be found in Chapter 2.

This report is organized as follows:

- Chapter 2 includes historical information to support the final status groundwater monitoring program determination.
- Chapter 3 describes the geology and hydrogeology of NRDWL.
- Chapter 4 describes the contaminant migration conceptual model.
- Chapter 5 describes groundwater flow simulations for the 200 East Area.
- Chapter 6 describes calculations performed to evaluate wells for the proposed NRDWL monitoring well network.
- Chapter 7 presents conclusions from the calculations performed in Chapters 5 and 6.

- Chapter 8 identifies the groundwater monitoring constituents of interest.
- Chapter 9 describes the proposed final status groundwater monitoring program.
- Chapter 10 describes how the monitoring well network will be maintained.
- Chapter 11 lists the references cited in this report.
- Appendix A contains the interim status groundwater monitoring data summary.
- Appendix B contains the topographic map.
- Appendix C contains regional plume maps in the vicinity of NRDWL.
- Appendix D contains well as-built diagrams.
- Appendix E contains the process for defining the groundwater monitoring statistical method.

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2 Supporting Historical Information

This chapter describes NRDWL and its operations, regulatory basis, waste characteristics, and interim status groundwater monitoring history.

2.1 Background

2.1.1 Facility Description

NRDWL is an inactive landfill located southeast of the 200 East Area and directly adjacent to SWL (Figure 2-1). Initially, NRDWL and SWL formally operated as a single landfill, referred to as the 600 Area Central Landfill, and the two landfills share a common perimeter fence. In 1975, the 600 Area Central Landfill was split into two units for operational purposes. At that time the northern unit became known as NRDWL (Figure 2-2) (Section 2.1 in DOE/RL-2017-19, *Groundwater Quality Assessment Plan for the Nonradioactive Dangerous Waste Landfill, Hanford Site*).

NRDWL is a 4.0 ha (10 ac) land disposal unit that consisted of 19 parallel, unlined trenches, each approximately 122 m (400 ft) long, 4.9 m (16 ft) wide at the base, and 4.6 m (15 ft) deep (Section 2.1 in DOE/RL-2017-19). Six trenches (26, 28, 31, 33, 34, and 19N) were used for the disposal of dangerous waste, with trench 19N receiving waste designated as oxidizers; trenches 26 and 28 receiving waste designated as corrosives; and trenches 31, 33, and 34 receiving waste designated as chemical (Figure 2-3). Nine trenches (2N, 20, 21, 22, 23, 25, 27, 29, and 30) were used for the disposal of asbestos waste, one trench (1N) was used exclusively for sanitary solid waste, and three trenches (18N, 24, and 32) were never used (Figures 2-2 and 2-3) (Chapter 1 in DOE/RL-2017-19).

2.1.2 Operational History

From 1975 until 1985, NRDWL received nonradioactive dangerous waste (chemical waste placed in metal drums) from Hanford Site operations. Nondangerous waste (solid waste and asbestos) was received until 1988, when the last receipt of asbestos occurred (Section 2.3 in DOE/RL-90-17, *Nonradioactive Dangerous Waste Landfill/Solid Waste Landfill Closure/Postclosure Plan*).

NRDWL provided for disposal of dangerous waste generated from process operations, research and development laboratories, maintenance activities, and transportation functions located throughout the Hanford Site. The landfill received containerized dangerous and extremely hazardous waste (chemical waste), asbestos, and nondangerous solid waste. Waste types are identified by trench on Figure 2-3. Most of the chemical waste was placed in metal drums. Nondangerous solid waste and asbestos were not generally placed in containers.

NRDWL trenches were excavated as landfill space was needed. Excavated soil was deposited on both sides of the trench in the form of spoil piles reserved for later use as cover material. Waste trucks would drive down into a trench and offload waste containers. At the end of an operating day, a portion of the spoil pile was bulldozed over the waste to form an approximate 3 m (10 ft) of operational cover (Section 2.1 in DOE/RL-2017-19).

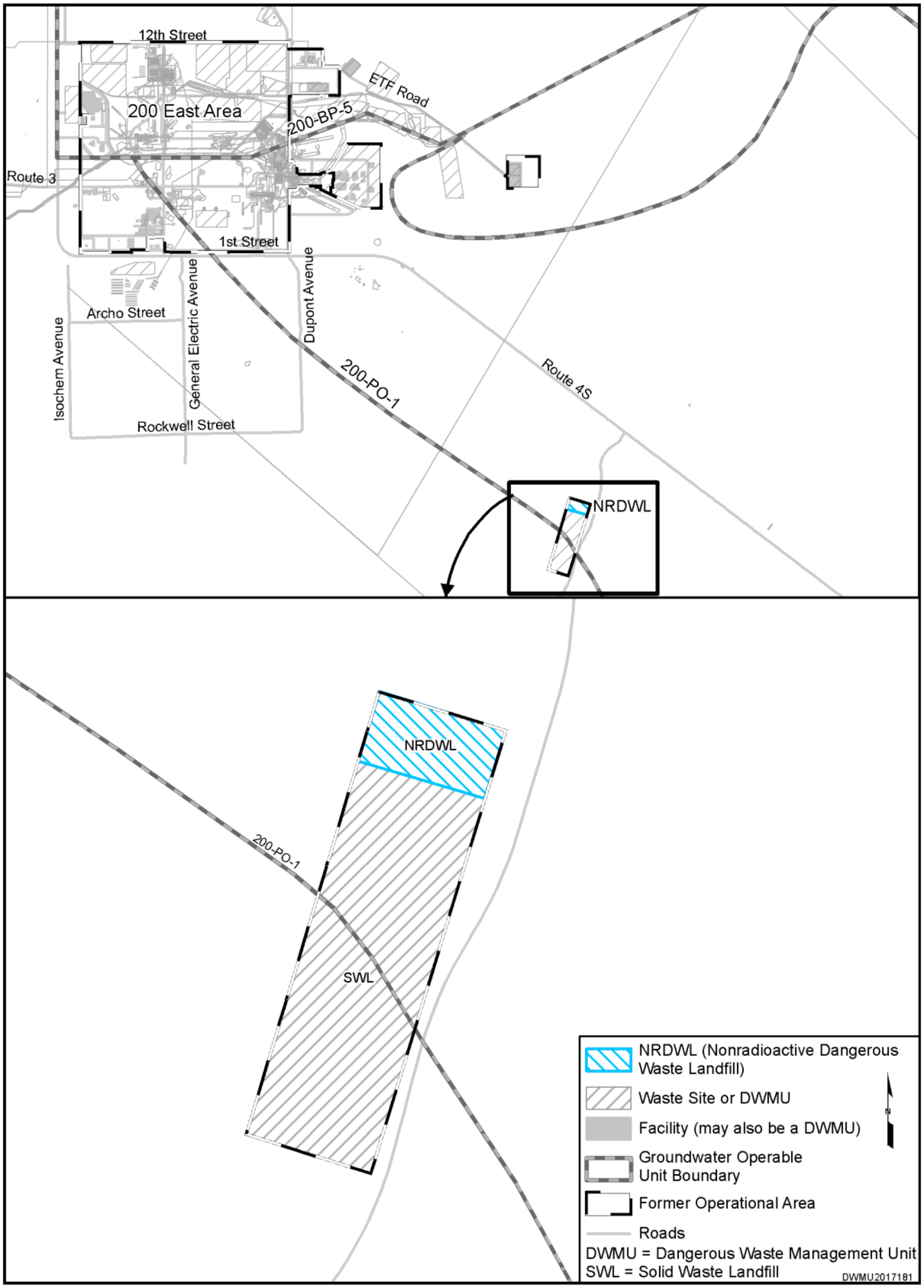
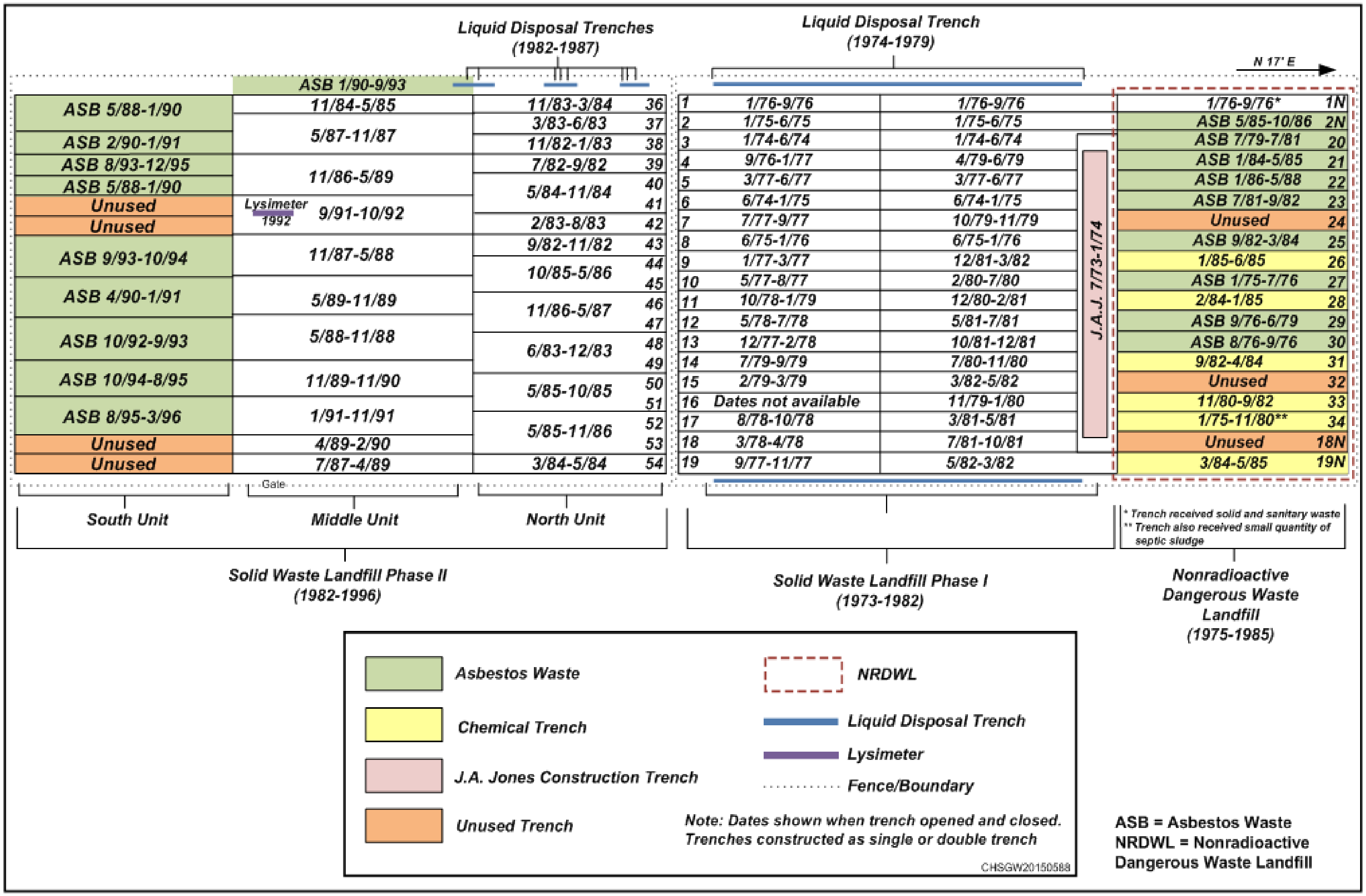


Figure 2-1. Location of NRDWL Southeast of the 200 East Area



Source: Figure 2-1 in DOE/RL-2017-19, *Groundwater Quality Assessment Plan for the Nonradioactive Dangerous Waste Landfill, Hanford Site*.

Figure 2-2. Schematic of Disposal Trench Configurations for NRDWL and Adjacent SWL

TRENCH – 1	Opened 1/76 – Closed 9/76	SANITARY
TRENCH – 2N	Opened 5/85 – Closed 10/86	ASBESTOS
TRENCH – 20	Opened 7/79 – Closed 7/81	ASBESTOS
TRENCH – 21	Opened 1/84 – Closed 5/85	ASBESTOS
TRENCH – 22	Opened 10/86 – Closed 5/88	ASBESTOS
TRENCH – 23	Opened 7/81 – Closed 9/82	ASBESTOS
TRENCH – 24		UNUSED
TRENCH – 25	Opened 9/82 – Closed 3/84	ASBESTOS
TRENCH – 26	Opened 1/85 – Closed 6/85	CORROSIVES
TRENCH – 27	Opened 1/75 – Closed 7/76	ASBESTOS
TRENCH – 28	Opened 2/84 – Closed 1/85	CORROSIVES
TRENCH – 29	Opened 9/76 – Closed 6/79	ASBESTOS
TRENCH – 30	Opened 8/76 – Closed 9/76	ASBESTOS
TRENCH – 31	Opened 9/82 - Closed 4/84	CHEMICAL
TRENCH – 32		UNUSED
TRENCH – 33	Opened 11/80 – Closed 9/82	CHEMICAL
TRENCH – 34	Opened 1/75 – Closed 11/80	CHEMICAL
TRENCH – 18N		UNUSED
TRENCH – 19N	Opened 3/84 – Closed 5/85	OXIDIZERS

Source: Figure 2-2 in DOE/RL-2017-19, *Groundwater Quality Assessment Plan for the Nonradioactive Dangerous Waste Landfill, Hanford Site*. Schematic is adapted from Figure 2 in WHC-SD-EN-AP-026, *Interim Status Groundwater Monitoring Plan for the Nonradioactive Dangerous Waste Landfill, Hanford, Washington*.

Figure 2-3. NRDWL Trench Schematic Indicating Numbering, Operational Dates, and Waste Designations

2.2 Regulatory Basis

In May 1987, DOE issued a final rule (10 CFR 962, "Byproduct Material") stating that the hazardous waste components of mixed waste are subject to RCRA regulations. The hazardous waste components of mixed waste were determined to be subject to Ecology authority to regulate these wastes since August 19, 1987.

In May 1989, DOE, the U.S. Environmental Protection Agency (EPA), and Ecology signed Ecology et al., 1989, *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement). This agreement established the roles and responsibilities of the agencies involved in regulating and controlling remedial restoration of the Hanford Site, which includes NRDWL. Groundwater monitoring is conducted at NRDWL in accordance with WAC 173-303-400(3), "Dangerous Waste Regulations," "Interim Status Facility Standards" (and, by reference, 40 CFR 265, Subpart F, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," "Ground-Water Monitoring"), which requires monitoring to determine whether the dangerous waste constituents from NRDWL have entered the groundwater in the uppermost aquifer underlying NRDWL.

Dangerous waste is regulated under RCW 70.105, "Hazardous Waste Management," and its Washington State implementing regulations (WAC 173-303). Radionuclides in mixed waste may include "source, special nuclear, and byproduct materials" as defined in the *Atomic Energy Act of 1954* (AEA). The AEA states that these radionuclide materials are regulated at DOE facilities, exclusively by DOE, acting pursuant to its AEA authority. Radionuclide materials are not hazardous/dangerous wastes and, therefore, are not subject to regulation by the State of Washington under RCRA or RCW 70.105.

In 1986, interim status groundwater monitoring at NRDWL was initiated under DOE, 1986, *Compliance Ground-Water Monitoring Plan for the Non-Radioactive Dangerous Waste Landfill on the Hanford Site*, based on the interim status indicator evaluation program requirements of 40 CFR 265, Subpart F, and WAC 173-303-400.

In 2001, specific conductance results exceeded the critical mean at NRDWL. The specific conductance exceedances were attributed to nondangerous constituents (calcium, bicarbonate, magnesium, and sulfate) from the adjacent SWL, as described in the 2001 letter report ("Conclusions and Recommendations" in 01-GWVZ-025, "Results of Assessment at the Non-Radioactive Dangerous Waste Landfill (NRDWL)") that was submitted to Ecology as required by WAC 173-303-400 and 40 CFR 265.93, "Preparation, Evaluation, and Response."

In 2008, the critical mean was exceeded for total organic carbon (TOC). After verification sampling confirmed the initial results, notification was submitted to Ecology on January 20, 2009 (09-AMCP-0058, "Notification of Exceedance of Critical Mean Values for an Indicator Parameter at Non-Radioactive Dangerous Waste Landfill and Low-Level Burial Grounds, Low-Level Waste Management Area 4"). A groundwater quality assessment plan (SGW-40274, 2009, *Groundwater Quality Assessment Plan for the Non-Radioactive Dangerous Waste Landfill*) was submitted to Ecology on January 30, 2009 (09-AMCP-0062, 2009, "First Determination Resource Conservation And Recovery Act Groundwater Quality Assessment Plans for the Non-Radioactive Dangerous Waste Landfill and the Low-Level Burial Grounds Low-Level Waste Management Area-4, SGW-40211, Revision 0"). Assessment sampling results detected only low levels of organics (Chapter 2 in SGW-41904, *Groundwater Quality Assessment Report for the Nonradioactive Dangerous Waste Landfill*), and no source for the elevated TOC results was identified. The first determination report concluded that NRDWL had not contaminated the groundwater and the unit returned to detection monitoring under PNNL-12227, *Groundwater Monitoring Plan for the Nonradioactive Dangerous Waste Landfill* (Section 3 in SGW-41904).

In 2010, a revised groundwater monitoring plan was proposed that combined NRDWL and SWL monitoring into a single plan (DOE/RL-2010-28, *Groundwater Monitoring Plan for the Nonradioactive Dangerous Waste Landfill and Solid Waste Landfill*). DOE/RL-2010-28 was issued in anticipation of approval of the revised RCRA closure/postclosure plan for the two landfills (DOE/RL-90-17). However, the combined monitoring plan and the revised closure/postclosure plan were not approved and groundwater monitoring continued under PNNL-12227.

In 2016, a revised indicator evaluation monitoring plan (DOE/RL-2015-32, *Groundwater Monitoring Plan for the Nonradioactive Dangerous Waste Landfill*) was issued. DOE/RL-2015-32 revised the monitoring network and modified the monitoring constituents.

In October 2016, specific conductance results exceeded the critical mean value at one downgradient well. Verification sampling in December 2016 confirmed the exceedance, after which Ecology was notified of the exceedance (17-AMRP-0089, "Notification of Exceedance of Critical Mean Values for Specific Conductance"). A groundwater quality assessment plan (DOE/RL-2017-19) was prepared and implemented at NRDWL in accordance with 40 CFR 265.93(3). Monitoring at NRDWL has since continued under a groundwater quality assessment program.

Under Revision 9 of the Hanford Facility Dangerous Waste Permit, NRDWL will become a final status closure unit group. Part II, Condition II.F of the Hanford Facility RCRA Permit specifies that final status groundwater monitoring program requirements will comply with WAC 173-303-645. This engineering evaluation report is prepared in accordance with WAC 173-303-806(4)(a)(xx)(E) and (F)(I) and (II) to implement the detection monitoring program requirements of WAC 173-303-645.

This engineering evaluation report also provides supporting information for Part B application general requirements of WAC 173-303-806(4)(a)(xx)(C) (topographic map), WAC 173-303-806(4)(a)(xx)(A) (summary of interim status groundwater monitoring data), and WAC 173-303-806(4)(a)(xx)(B) (hydrogeological information). Plume maps of any regional contaminants in the vicinity of the regulated unit are provided in Appendix C.

2.3 Waste Characteristics

At NRDWL, disposal of dangerous waste was limited to trenches 26, 28, 31, 33, 34, and 19N (Figures 2-2 and 2-3). Most of the chemical waste at NRDWL was containerized in 208 L (55 gal) drums prior to disposal (Section 2.1.3 in WHC-SD-EN-AP-026, *Interim Status Groundwater Monitoring Plan for the Nonradioactive Dangerous Waste Landfill, Hanford, Washington*). Containers holding small quantities of laboratory chemicals, paints, and other wastes were placed in 208 L (55 gal) drum labpacks and surrounded with sufficient sorbing material to absorb any leaking liquids. No containers holding free liquids are known to have been placed in NRDWL. Some of the bulk organic wastes that were sorbed onto soil and other sorbents may not have been containerized. Nonhazardous waste and asbestos waste generally were not containerized prior to disposal. Empty containers (both regulated and nonregulated) that once held regulated nonradioactive dangerous waste were disposed to NRDWL. These empty containers consisted primarily of metal and fiber drums (Section 3.1 in DOE/RL-90-17).

Waste disposed to NRDWL comprises the following categories (Section 2.1.3 in WHC-SD-EN-AP-026):

- Chemical Waste
  - Small-quantity nonradioactive laboratory chemicals. This category includes unused inorganic and organic chemical reagents, out-of-date reagent chemicals, spent laboratory chemicals, and laboratory formulations. These chemicals consisted primarily of metallic salts, acids, bases, oxidizers, organic chemicals, and flammable materials.

   - Bulk organic waste. This category includes nonradioactive solvent waste, paints, paint thinners, and waste oils. These materials account for approximately 50% of the total mass of chemical waste disposed in the landfill. The largest quantities of these wastes consisted of solvent wastes, paints, paint thinners, and waste oils absorbed onto solids and placed in trenches 33 and 34. Nonregulated oil-soaked sand was placed in trench 26.
   - Metal cleaner waste. This category includes various metal cleaners, some of which were made up of a mixture of sulfamic acid and sodium bisulfate. These wastes were disposed of in trench 34.

- Asbestos. This category includes asbestos or material containing asbestos that was nonradioactive and nonhazardous waste generated from building demolition or renovation activities. These materials, which accounted for more than 50% by volume of the waste disposed at NRDWL, are present in 9 of the 16 trenches containing waste.

- Nonhazardous Solid Waste. This category includes office and lunchroom waste and construction and demolition debris. Trench 1N was dedicated for receiving sanitary solid waste. One instance of the disposal of septic tank sludge occurred in January 1976 in trench 34.

The dangerous wastes managed at NRDWL are identified in the Hanford Facility RCRA Permit Part A Application for the unit (Table 2-1).

Table 2-1. Dangerous Wastes Identified for NRDWL in the Hanford Facility RCRA Permit Part A Application

Dangerous Waste Code	Contaminant Description*	Dangerous Waste Code	Contaminant Description*
D001	Ignitable waste	U051	Creosote
D002	Corrosive waste	U053	2-Butenal
D003	Reactive waste	U056	Benzene, hexahydro- (I), cyclohexane (I)
D004	Arsenic	U069	1,2-Benzenedicarboxylic acid, dibutyl ester, dibutyl phthalate
D005	Barium	U070	Benzene, 1,2-dichloro-, o-dichlorobenzene
D006	Cadmium	U077	Ethane, 1,2-dichloro-, ethylene dichloride
D007	Chromium	U080	Methane, dichloro-, methylene chloride
D008	Lead	U092	Dimethylamine (I), methanamine, N-methyl- (I)
D009	Mercury	U093	Benzenamine, N,N-dimethyl-4-(phenylazo)-, p-dimethylaminoazobenzene
D010	Selenium	U108	1,4-Diethyleneoxide, 1,4-dioxane
D011	Silver	U117	Ethane, 1,1'-oxybis-(I), ethyl ether (I)
D018	Benzene	U122	Formaldehyde
D019	Carbon tetrachloride	U123	Formic acid (C,T)
D022	Chloroform	U133	Hydrazine (R,T)
D039	Tetrachloroethylene	U134	Hydrofluoric acid (C,T), hydrogen fluoride (C,T)
D040	Trichlorethylene	U142	Kepone

Table 2-1. Dangerous Wastes Identified for NRDWL in the Hanford Facility RCRA Permit Part A Application

Dangerous Waste Code	Contaminant Description*	Dangerous Waste Code	Contaminant Description*
F001	Spent halogenated solvents (T)	U144	Acetic acid, lead(2+) salt, lead acetate
F002	Spent halogenated solvents (T)	U151	Mercury
F003	Spent nonhalogenated solvents (I)	U154	Methanol (I), methyl alcohol (I)
F004	Spent nonhalogenated solvents (T)	U159	2-Butanone (I,T), methyl ethyl ketone (MEK) (I,T)
F005	Spent nonhalogenated solvents (I,T)	U161	4-Methyl-2-pentanone (I), methyl isobutyl ketone (I), pentanol, 4-methyl-
P010	Arsenic acid	U169	Benzene, nitro-, nitrobenzene (I,T)
P012	Arsenic oxide, Arsenic trioxide	U188	Phenol
P022	Carbon disulfide	U196	Pyridine
P030	Cyanides (soluble cyanide salts), not otherwise specified	U201	1,3-Benzenediol, resorcinol
P048	2,4-Dinitrophenol, phenol, 2,4-dinitro-	U210	Ethene, tetrachloro-, tetrachloroethylene
P096	Hydrogen phosphide, phosphine	U211	Carbon tetrachloride, methane, tetrachloro-
P098	Potassium cyanide, potassium cyanide K(CN)	U213	Furan, tetrahydro-(I), tetrahydrofuran (I)
P106	Sodium cyanide, sodium cyanide Na(CN)	U219	Thiourea
U001	Acetaldehyde (I), ethanal (I)	U220	Benzene, methyl-, toluene
U002	2-Propanone (I), acetone (I)	U226	Ethane, 1,1,1-trichloro-, methyl chloroform
U003	Acetonitrile (I,T)	U228	Ethene, trichloro-, trichloroethylene
U007	2-Propenamide, acrylamide	U239	Benzene, dimethyl- (I,T), xylene (I)
U009	2-Propenenitrile, acrylonitrile	WT01	Toxic dangerous waste, extremely hazardous
U012	Aniline (I,T), benzenamine (I,T)	WT02	Toxic dangerous waste
U019	Benzene (I,T)	WP01	Persistent dangerous wastes halogenated organic compounds - extremely hazardous waste
U022	Benzo[a]pyrene	WP02	Persistent dangerous wastes halogenated organic compounds - dangerous waste
U031	1-Butanol (I), n-Butyl alcohol (I)	WP03	Polycyclic aromatic hydrocarbons - extremely hazardous waste

Table 2-1. Dangerous Wastes Identified for NRDWL in the Hanford Facility RCRA Permit Part A Application

Dangerous Waste Code	Contaminant Description*	Dangerous Waste Code	Contaminant Description*
U044	Chloroform	--	--

Source: Enclosure 3 in 09-EMD-0007, "Class 1 Modifications to the Hanford Facility Resource Conservation and Recovery Act Permit, Quarter Ending September 30, 2008"

*Dangerous waste code contaminant descriptions from WAC 173-303-090, "Dangerous Waste Regulations," "Dangerous Waste Characteristics"; WAC 173-303-104, "State-Specific Dangerous Waste Numbers"; WAC 173-303-9903, "Discarded Chemical Products List"; and WAC 173-303-9904, "Dangerous Waste Sources List."

C = corrosive waste
I = ignitable waste
R = reactive waste
T = toxic waste

2.4 Interim Status Monitoring Network and Sampling History

Table 2-2 identifies the interim status groundwater monitoring plans implemented at NRDWL. Figure 2-4 provides the locations of wells discussed in this section. A summary of the monitoring history for NRDWL is presented in Appendix A. Appendix A also contains the interim status groundwater monitoring data collected at NRDWL network wells and meets the requirement of WAC 173-303-806(4)(a)(xx)(A). The status of the monitoring wells through the plans indicated in Table 2-2 is provided in Appendix A.

Groundwater monitoring was initiated at NRDWL in 1986 in accordance with a compliance groundwater monitoring plan (DOE, 1986) that was prepared in response to a joint regulatory order (EPA and Ecology, 1986, EPA Regulatory Order No. 1085-10-07-3008 and Ecology No. DE 86-132 and DE 86-133). Groundwater monitoring was based on the interim status indicator evaluation program requirements of 40 CFR 265, Subpart F, and WAC 173-303-400. The plan called for drilling one upgradient and three downgradient wells to monitor the upper portion of the unconfined aquifer, and one upgradient deep well and one downgradient deep well for information only (p. 9 in DOE, 1986). Monitoring constituents included the contamination indicator parameters, groundwater quality parameters, and drinking water parameters required by 40 CFR 265.92(b), "Sampling and Analysis," bicarbonate, carbonate, calcium, magnesium, and potassium (Table 3 in DOE, 1986).

By 1987, nine wells were drilled for NRDWL including two upgradient wells (699-26-34 [later renamed 699-36-34A] and 699-26-35A), three downgradient wells (699-25-34A, 699-25-34B, and 699-26-33), two deep information only wells (upgradient well 699-26-35C and downgradient well 699-25-33A), and three deep observation wells (upgradient well 699-26-35B and downgradient wells 699-25-33B [abandoned in 1986] and 699-26-35D) (Tables 3-1, 3-2, and 3-3 in WHC-EP-0021, *Interim Hydrogeologic Characterization Report and Groundwater Monitoring System for the Nonradioactive Dangerous Waste Landfill, Hanford Site, Washington*). The deep information only wells (699-26-35C and 699-25-33A) were completed in the top of a low-permeability unit in the upper Ringold Formation. Observation wells 699-25-33B and 699-26-35D were not reported as part of the network after 1988 (Figure 5.1 in PNL-6852, *RCRA Ground-Water Monitoring Projects for Hanford Facilities: Annual Progress Report for 1988*, and Figure 5.1 in PNNL-7305, *RCRA Ground-Water Monitoring Projects for Hanford Facilities: Annual Progress Report for 1989*). The groundwater flow rate at NRDWL ranged from 0.6 to 1.5 m/d (2 to 5 ft/d), with a flow direction to the east (Sections 5.3.4.4 and 6.0 in WHC-EP-0021).

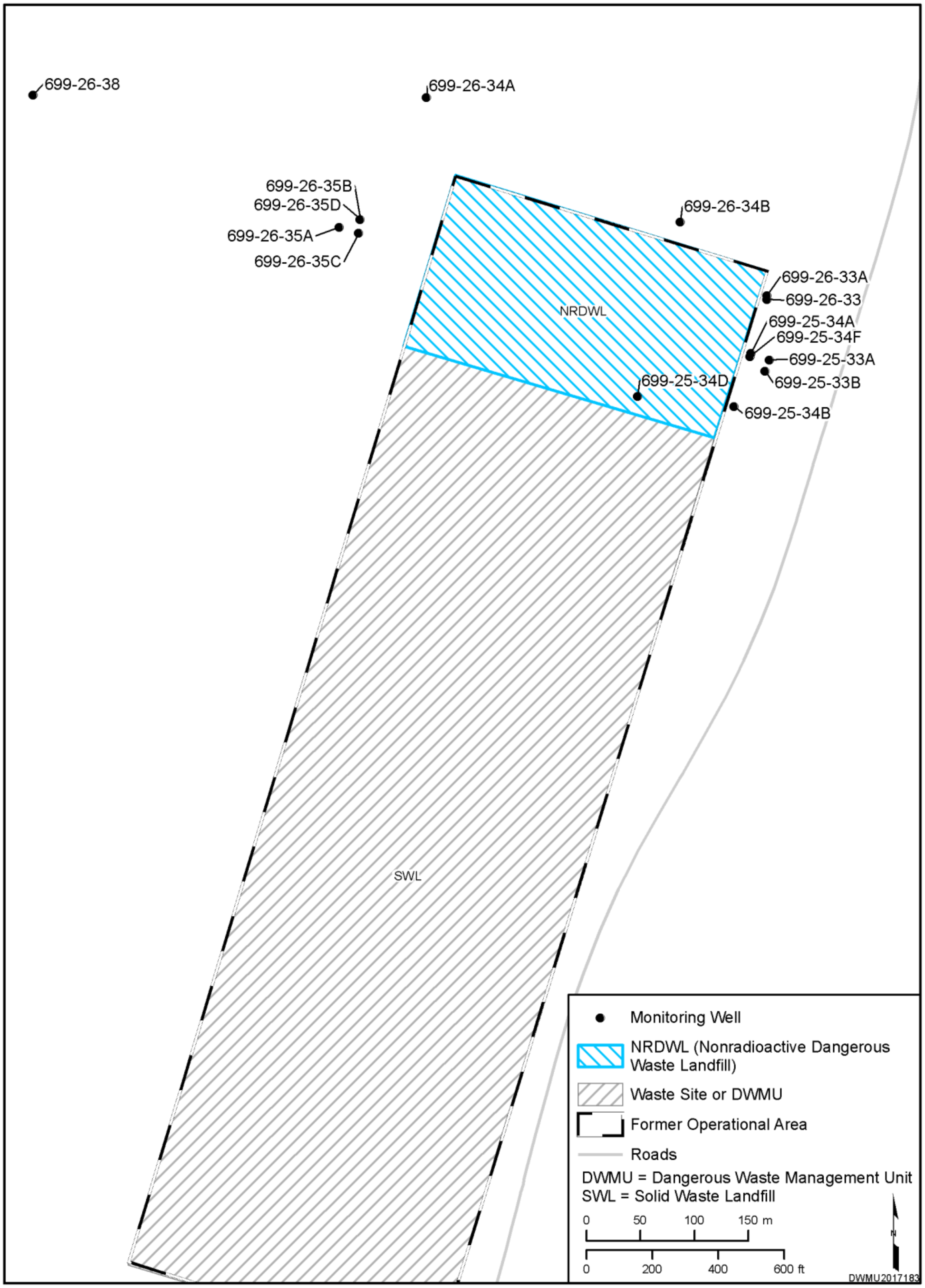


Figure 2-4. Wells Used During Interim Status Monitoring of NRDWL

Table 2-2. Interim Status Monitoring Plans

Document	Date	Monitoring Program[a]
DOE, 1986, *Compliance Ground-Water Monitoring Plan for the Non-Radioactive Dangerous Waste Landfill on the Hanford Site*	1986	Indicator Evaluation Program
WHC-SD-EN-AP-026, *Interim Status Groundwater Monitoring Plan for the Nonradioactive Dangerous Waste Landfill, Hanford, Washington*, Rev. 0 ECN 634620, WHC-SD-EN-AP-026, Rev. 0-A	1993 1996	Indicator Evaluation Program
PNNL-12227, *Groundwater Monitoring Plan for the Nonradioactive Dangerous Waste Landfill* ICN-PNNL-12227	1999 2001	Indicator Evaluation Program
SGW-40274, *Groundwater Quality Assessment Plan for the Non-Radioactive Dangerous Waste Landfill*	2009	Groundwater Quality Assessment Program[b]
DOE/RL-2015-32, *Groundwater Monitoring Plan for the Nonradioactive Dangerous Waste Landfill*, Rev. 0	2016	Indicator Evaluation Program
DOE/RL-2017-19, *Groundwater Quality Assessment Plan for the Nonradioactive Dangerous Waste Landfill, Hanford Site*, Rev. 0	2017	Groundwater Quality Assessment Program

a. The Indicator Evaluation Program satisfies the requirements of 40 CFR 265.92(b), (d)(1), (d)(2), and (e), "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," "Sampling and Analysis." The groundwater quality assessment program's first determination satisfies the requirements of 40 CFR 265.93(d)(4) and (d)(6), "Preparation, Evaluation, and Response." The groundwater quality assessment program's first determination satisfies the requirements of 40 CFR 265.93(d)(4) and (d)(6), "Preparation, Evaluation, and Response."

b. After completion of the first determination report in 2009 (SGW-41904, *Groundwater Quality Assessment Report for the Nonradioactive Dangerous Waste Landfill*), indicator evaluation monitoring was reinstated at the Nonradioactive Dangerous Waste Landfill under PNNL-12227 and ICN-PNNL-12227.

ICN = interim change notice

From July 1988 to August 1989, sampling was not performed at NRDWL due to problems associated with the disposal of purgewater; therefore, the quarterly sampling that had been initiated in 1987 was not completed until the third quarter of 1989 (Section 3.1 in WHC-SD-EN-AP-026). Groundwater sampling was temporarily discontinued in June 1990 due to cancelation of the analytical laboratory contract. Sampling at NRDWL wells resumed in August 1991 (Section 3.1 in WHC-SD-EN-AP-026).

In 1993, a shallow vadose zone soil-gas survey was done at NRDWL and adjacent portions of SWL (Section 5.2.3 in DOE/RL-93-88, *Annual Report for RCRA Groundwater Monitoring Projects at Hanford Site Facilities for 1993*). The results indicated the widespread occurrence of acetone and several chlorinated hydrocarbons in the shallow vadose zone. The chlorinated hydrocarbons with the widest distribution in the shallow vadose zone were trichloroethene (TCE) and tetrachloroethene (PCE), with PCE being the most persistent and occurring at the highest concentrations. Other chlorinated hydrocarbons that occurred more locally included 1,1,1-trichloroethane (TCA), carbon tetrachloride, and chloroform. The highest concentrations of chlorinated hydrocarbons occurred over the older chemical trenches near the east end of NRDWL (see Section 4.1.1 for discussion of the soil-gas survey results).

In 1993, a revised monitoring plan was issued (WHC-SD-EN-AP-026) that proposed three additional wells: two shallow monitoring wells and one deep monitoring well (Section 3.4.4 in WHC-SD-EN-AP-026). The locations for the new wells were based on uncertainties in groundwater flow directions and the need for characterization of the deeper portions of the unconfined aquifer beneath the unit (Section 3.4.5 in WHC-SD-EN-AP-026). A proposed shallow well located to the north of NRDWL (699-26-34B) was to supplement the downgradient network, and a proposed shallow well located to the south of NRDWL (699-25-34D) was to help distinguish between potential groundwater impacts from NRDWL and SWL (Section 3.4.5 in WHC-SD-EN-AP-026). The proposed deep monitoring well (to be located adjacent to the planned shallow monitoring well on the south side of NRDWL [699-25-34D]) was intended to characterize the deep aquifer and detect dense nonaqueous-phase liquid (DNAPL) contaminants (Section 3.4.5 in WHC-SD-EN-AP-026). Deep observation wells 699-25-33B and 699-26-35D were no longer in use and were not included in the monitoring network (Sections 3.4.2 and 3.4.3 in WHC-SD-EN-AP-026). The monitoring constituents included the contamination indicator parameters, groundwater quality parameters, and drinking water parameters required by 40 CFR 265.92(b), tritium; and volatile halogenated hydrocarbons (Table 4 in WHC-SD-EN-AP-026). The groundwater flow direction was uncertain. Regional flow patterns suggested a southeast direction, but the configuration of nitrate and tritium plumes from the 200 East Area indicated a direction that was 120º to 130º east of north (Section 2.3.3.1 in WHC-SD-EN-AP-026).

The 1993 RCRA report included the two new shallow wells (699-25-34D and 699-26-34B) in the monitoring network, which comprised two upgradient wells (699-26-34A and 699-26-35A), five downgradient wells (699-25-34A, 699-25-34B, 699-25-34D, 699-26-33, and 699-26-34B), and two information only wells monitoring the top of the low-permeability unit (upgradient well 699-26-35C and downgradient well 699-25-33A) (Table 5.2-1 in DOE/RL-93-88).

In 1995, Engineering Change Notice (ECN) 634620 to WHC-SD-EN-AP-026 documented the installation of the two downgradient wells (699-25-34D and 699-26-34B) (Table 1 in ECN 634620). The proposed deep well had not been drilled and remained as a proposed well (Section 3.4.5 in ECN 634620). The monitoring constituents included the contamination indicator parameters and groundwater quality parameters required by 40 CFR 265.92(b), barium, chromium, fluoride, nitrate, gross alpha, gross beta, coliform, tritium, and volatile halogenated hydrocarbons (Table 4 in ECN 634620).

In 1999, PNNL-12227 was issued to incorporate previous well network changes and revise the monitoring constituents. The monitoring network comprised two upgradient wells (699-26-34A and 699-26-35A), five downgradient wells (699-25-34A, 699-25-34B, 699-25-34D, 699-26-33, and 699-26-34B), and two information only wells monitoring the top of the low-permeability unit (upgradient well 699-26-35C and downgradient well 699-25-33A) (Table 5-1 in PNNL-12227). The monitoring constituents included the contamination indicator parameters and groundwater quality parameters required by 40 CFR 265.92(b), volatile chlorinated hydrocarbons, and nitrate.

In March 2001, ICN-PNNL-12227, *Interim Change Notice to Groundwater Monitoring Plan for the Nonradioactive Dangerous Waste Landfill*, was issued to eliminate the requirement to collect quadruplicate groundwater samples from the two deep wells (699-25-33A and 699-26-35C) since the data were not used for statistical comparisons (Section D in ICN-PNNL-12227).

In March 2001, specific conductance results in two downgradient wells (699-25-34A and 699-25-34B) exceeded the critical mean and a notification was transmitted to Ecology (01-GWVZ-023, "Notification of Specific Conductance Exceedance at the Non-Radioactive Dangerous Waste Landfill (NRDWL)"). In June 2001, DOE submitted a letter report (01-GWVZ-025) to Ecology that concluded that the increased specific conductance was likely caused by increases in the concentrations of nonhazardous constituents (bicarbonate, sulfate, calcium, and magnesium) from SWL and recommended that NRDWL remain in an indicator evaluation program ("Conclusions and Recommendations" in 01-GWVZ-025). Exceedances of the specific conductance critical mean at NRDWL monitoring wells continued, with occurrences in 2002, 2005, 2007, 2009, 2010, 2011, and 2014; however, the elevated results were attributed to nonhazardous constituents from SWL (Section A.1.16 in PNNL-14187, *Hanford Site Groundwater Monitoring for Fiscal Year 2002*; Section 2.11.3.7 in PNNL-15670, *Hanford Site Groundwater Monitoring for Fiscal Year 2005*; Section 2.11.3.7 in DOE/RL-2008-01, *Hanford Site Groundwater Monitoring for Fiscal Year 2007*; Section 5.4.6.3 in DOE/RL-2010-11, *Hanford Site Groundwater Monitoring and Performance Report for 2009*; Section 10.3.6.2 in DOE/RL-2011-01, *Hanford Site Groundwater Monitoring Report for 2010*; Section 3.5.9.8 in DOE/RL-2011-118, *Hanford Site Groundwater Monitoring for 2011*; and Section 10.13.7 in DOE/RL-2015-07, *Hanford Site Groundwater Monitoring Report for 2014*).

In August 2008, TOC results from downgradient wells 699-25-34A and 699-25-34B exceeded the critical mean value. Verification sampling results in October 2008 confirmed the initial results for well 699-25-34B (Chapter 1.0 in SGW-40274), and NRDWL subsequently entered a groundwater quality assessment program as required by 40 CFR 265.93(d)(4). The source of the elevated organic carbon was uncertain. Chlorinated hydrocarbons had been disposed at NRDWL and adjacent SWL; however, the concentrations (less than 1 µg/L) of chlorinated hydrocarbons detected in the NRDWL well network were too low to account for the elevated TOC (Section 1.0 in SGW-40274)**.** Sewage disposed to two liquid discharge trenches at SWL was considered the likely source for the elevated TOC**.**

The monitoring well network in the groundwater quality assessment plan included only downgradient wells 699-25-34A, 699-25-34B, and 699-25-34D, with the remaining network wells to be included under an expanded assessment, if needed (Section 2.1 in SGW-40274). The monitoring constituents included the organic compounds of 40 CFR 264, "Standards for Owners and Operators of Hazardous Waste Treatment Storage, and Disposal Facilities," Appendix IX, "Ground-Water Monitoring List"; total petroleum hydrocarbons for diesel, gas, and oil; oil and grease; coliform bacteria; and chemical oxygen demand (Section 2.2 in SGW-40274). Monitoring under the indicator parameter program (PNNL-12227 and ICN-PNNL-12227) was to continue during the assessment (Section 2.2 in SGW-40274). The groundwater flow direction was reported as east-southeast (Section 2.1 in SGW-40274).

In March 2009, assessment sampling was performed, and a first determination report (SGW-41904) was issued in August 2009. Sampling results included low-level detections of organics, which were qualified as estimated (Chapter 2 in SGW-41904). Results for sewage-related parameters (coliform bacteria, dissolved oxygen, chemical oxygen demand, and oxidation-reduction potential) were typical of other area wells (such as upgradient wells at NRDWL) that were not contaminated with sewage. The report concluded that NRDWL had not contaminated the unconfined aquifer with dangerous waste constituents and that the monitoring results did not support the hypothesis that the elevated TOC was from sewage disposal at SWL (Section 3 in SGW-41904). NRDWL subsequently returned to an indicator evaluation monitoring program under PNNL-12227 and ICN-PNNL-12227. The monitoring network was unchanged with two upgradient wells (699-26-34A and 699-26-35A) and five downgradient wells (699-25-34A, 699-25-34B, 699-25-34D, 699-26-33, and 699-26-34B), and two information only wells monitoring the top of the low-permeability unit (upgradient well 699-26-35C and downgradient well 699-25-33A) (Table B-26 in DOE/RL-2011-01).

In 2010, a groundwater monitoring plan combining NRDWL and SWL monitoring activities (DOE/RL-2010-28) was issued in anticipation of approval of the revised RCRA closure/postclosure plan (DOE/RL-90-17) for the two landfills. Groundwater monitoring in DOE/RL-2010-28 was designed for final status permit conditions under WAC 173-303-645. Pending approval of DOE/RL-90-17, the combined groundwater monitoring plan for NRDWL and SWL was to be implemented during the closure and postclosure period of NRDWL and SWL. DOE/RL-2010-28 proposed two new upgradient wells for NRDWL and SWL that would be located distant enough upgradient to avoid groundwater contamination by volatile organic compounds (VOCs) (Section 4.4 in DOE/RL-2010-28). DOE/RL-90-17 was not approved and DOE/RL-2010-28 was not utilized for groundwater monitoring; however, a far-field upgradient monitoring well (699-26-38) was completed in 2014 and was planned to be integrated into the NRDWL monitoring network (Section 10.13.7 in DOE/RL-2015-07).

Beginning in 2013, the designation of well 699-26-34B was reported as sidegradient (p. PO-43 in DOE/RL-2014-32, *Hanford Site Groundwater Monitoring Report for 2013*). In 2014, wells 699-25-34A and 699-26-33 were planned for replacement as they were going dry (Section 10.13.7 in DOE/RL-2015-07). In 2015, replacement wells 699-25-34F and 699-26-33A were installed and were to be added to the network when the monitoring plan was revised (Section 2.16 in DOE/RL-2016-12, *Hanford Site RCRA Groundwater Monitoring Report for 2015*).

In 2016, a revised indicator evaluation monitoring plan (DOE/RL-2015-32) was issued to revise the monitoring network and modify the monitoring constituents. The plan incorporated recently installed upgradient well (699-26-38), which provided additional upgradient groundwater information at a location far enough upgradient of the NRDWL and SWL sites to minimize the effects of VOCs from soil-gas vapor in the vadose zone detected by upgradient wells located closer to NRDWL (699-26-35A and 699-26-34A) (Section 3.2 in DOE/RL-2015-32). Additionally, new downgradient wells 699-26-33A and 699-25-34F were added to the network to replace wells 699-26-33 and 699-25-34A, which were sample dry (Section 3.3 in DOE/RL-2015-32). The well network in DOE/RL-2015-32 comprised three upgradient wells (699-26-34A, 699-26-35A, and 699-26-38), three downgradient wells (699-25-34B, 699-25-34F, and 699-26-33A), two cross-downgradient wells (699-25-34D and 699-26-34B), and two deep information only wells (699-25-33A and 699-26-35C) (Tables 3-1 and 3-3 in DOE/RL-2015-32). The monitoring constituents included the contamination indicator parameters, groundwater quality parameters, and drinking water parameters required by 40 CFR 265.92(b), metals, anions, alkalinity, and VOCs (TCA, TCE, PCE, chloroform, 1,1-dichloroethane, and carbon tetrachloride).

In October 2016, elevated specific conductance was measured at downgradient well 699-25-34B. Verification sampling, completed in December 2016 after cleaning and maintenance of the well, confirmed the exceedance. Ecology was notified of the exceedance (17-AMRP-0089). In 2017, NRDWL entered a groundwater quality assessment monitoring program under DOE/RL-2017-19. The monitoring network remained the same as that in DOE/RL-2015-32 (Table 3-2 in DOE/RL-2017-19). The monitoring constituents included the waste constituents in Appendix 5 of Ecology Publication No. 97-407, *Chemical Test Methods For Designating Dangerous Waste WAC 173-303-090 & -100*, alkalinity, anions, metals, TOC, total organic halogens, pH, specific conductance, temperature, and turbidity (Table 3-2 in DOE/RL-2017-19). Monitoring at NRDWL has since continued under the groundwater quality assessment program and DOE/RL-2017-19.

3 Geology and Hydrogeology

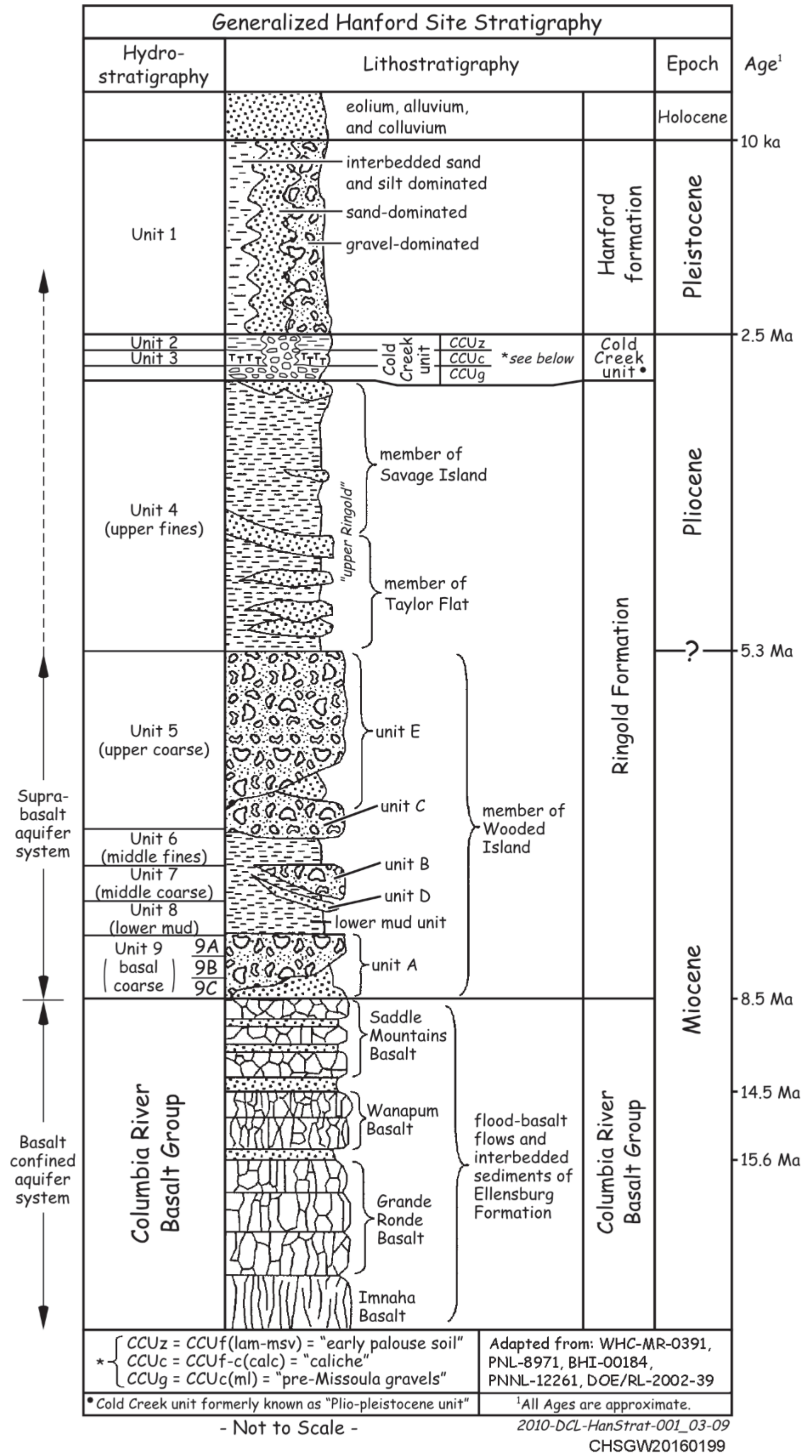
This chapter briefly describes the local geology and hydrogeology beneath NRDWL and is included to provide a brief overview of the current understanding of the site. The information provided is summarized from several sources, including the following: Section 3.4 in DOE/RL-2009-85, *Remedial Investigation Report for the 200-PO-1 Groundwater Operable Unit*; Sections 3.1.3 and 4.2 in WHC-SD-EN-TI-012, *Geologic Setting of the 200 East Area: An Update*; Section 2.5 in PNNL-19277, *Conceptual Models for Migration of Key Groundwater Contaminants Through the Vadose Zone and Into the Unconfined Aquifer Below the B-Complex*; and Chapter 5 of BHI-00184, *Miocene- to Pliocene-Aged Suprabasalt Sediments of the Hanford Site*. The information provided in this chapter is in alignment with ECF-HANFORD-13-0029, Rev. 5, *Development of the Hanford South Geologic Framework Model, Hanford Site, Washington*, and CP-60925, *Model Package Report: Central Plateau Vadose Zone Geoframework Version 1.0*.

In addition, Chapter 3 in PNNL-12261, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-East Area and Vicinity, Hanford Site, Washington;* Section 2.2 in SGW-54165, *Evaluation of the Unconfined Aquifer Hydraulic Gradient Beneath the 200 East Area, Hanford Site*; and Chapter 4.0 in WHC-SD-EN-TI-012 provide information on the hydrogeology of the 200 East Area and vicinity.

3.1 Stratigraphy

A generalized stratigraphic column for the Hanford Site and another stratigraphic column for NRDWL/SWL are presented in Figure 3-1. The local stratigraphy beneath NRDWL consists of approximately 175 m (575 ft) of unconsolidated to semiconsolidated sediments overlying the basalt bedrock of the Columbia River Basalt Group. Geologic cross sections are shown in Figures 3-2 and 3-3. The stratigraphic units present within the vicinity of NRDWL (listed from youngest to oldest) are as follows:

- Sand and gravel backfill and/or Holocene eolian silty sand
- Sand and gravel of the Hanford formation
  - Middle sand-dominated facies (H2)
  - Lower gravel-dominated facies (H3)
- Sand and gravel of the Cold Creek unit (CCU_g)
- Sandy silt, sand, and gravelly sand of the Ringold Formation member of Taylor Flat (Rtf)
- Ringold Formation member of Wooded Island
  - Sand, silt, and gravel of the Ringold Formation member of Wooded Island unit E (Rwie)
  - Fine-grained Ringold Formation member of Wooded Island lower mud unit (Rlm)
  - Sand and gravel of the Ringold Formation member of Wooded Island unit A (Rwia) (which overlies basalt)



Note: Complete reference citations are provided in Chapter 11.

Figure 3-1. General Stratigraphy of the Hanford Site

The Hanford formation (equivalent to hydrostratigraphic unit 1 [HSU 1] in Figure 3-1) is an informal stratigraphic unit consisting of uncemented gravel, sand, and silt deposited by the late Pleistocene Missoula cataclysmic glacial floods (Section 3.1.3.3 in WHC-SD-EN-TI-012). The Hanford formation is divided into three facies sub-units (silt-dominated, sand-dominated, and gravel-dominated) that grade into one another both vertically and laterally with distance from the main high-energy flood currents (Section 2.5.2 in PNNL-19277). On the Central Plateau, the Hanford formation is sometimes further delineated into H1, H2, and H3 lithographic facies. Units H1 and H3 consist of coarse-grained, basalt-rich sandy gravels with varying amounts of silt/clay. These gravel units may also contain interbedded sand and or silt/clay lenses. The H2 sequence is dominated by sand to gravelly sand, with minor sandy gravel or silt/clay interbeds. Both the sand-dominated H2 and gravel-dominated H3 sequences are present beneath NRDWL (Figures 3-2 and 3-3), and the Hanford formation is expected to be approximately 40 m (130 ft) thick.

The Hanford formation gravel-dominated sequence (H3) overlies the CCU_g (also referred to as pre-Missoula gravels) beneath NRDWL. In much of the 200 East Area, the CCU_g is characterized as an unconsolidated coarse-grained, moderately felsic gravel that varies from a sandy gravel with cobbles to a silty gravelly sand, located above the Ringold Formation and below the more basaltic Hanford formation (Section 3.1.2 in PNNL-16407, *Geology of the Waste Treatment Plant Seismic Boreholes*; Section 3.1 in DOE/RL-2002-39, *Standardized Stratigraphic Nomenclature for Post-Ringold-Formation Sediments Within the Central Pasco Basin*; and Section 3.4 in DOE/RL-2009-85). Within the vicinity of NRDWL, the CCU_g is expected to range from 17 to 23 m (56 to 75 ft) thick.

The Ringold Formation consists of Miocene-Pliocene fluvial and lacustrine clastic sediment deposited by the ancestral Columbia River system, and rests unconformably on the Miocene-age Columbia River Basalt Group. The Ringold Formation was subdivided into three facies in BHI-00184. The Ringold Formation immediately underlying the CCU_g at NRDWL belongs to the member of Taylor Flat (equivalent to HSU 4) (Figure 3-1), but lateral continuity beyond NRDWL/SWL is uncertain. Fluvial deposits consisting of slightly silty gravelly sand to sand, clayey silt, and silty sands to silty gravelly sand dominate this unit. A thin, vertical sequence within the Rtf contains silt and clay bedding. This sequence has historically been informally referred to as the “low permeability unit” based on its lithologic and hydrologic characteristics.

The Ringold member of Wooded Island, the lowest of the Ringold facies identified in BHI-00184, underlies the Rtf at NRDWL. The member of Wooded Island is further divided into five gravel-dominated, fluvial depositional units, separated by widespread overbank, paleosol, and lacustrine deposits (BHI-00184). Of these five units, the Rwie, the Rlm, and the Rwia are present in the vicinity of NRDWL and are further described below:

- The Rwie (equivalent to HSU 5) underlies the Rtf in the vicinity of NRDWL. The Rwie consists of fluvial deposits with thick layers of silty sandy gravel (conglomerate) intercalated with thinner beds of overbank silts and fine-grained paleosol. Beneath SWL, it is undifferentiated from Ringold Formation member of Wooded Island unit C (another coarse-grained Ringold Formation unit) that may be present beneath Rwie (Figure 3-1). Beneath NRDWL, the Rwie is expected to be approximately 57 m (187 ft) thick.

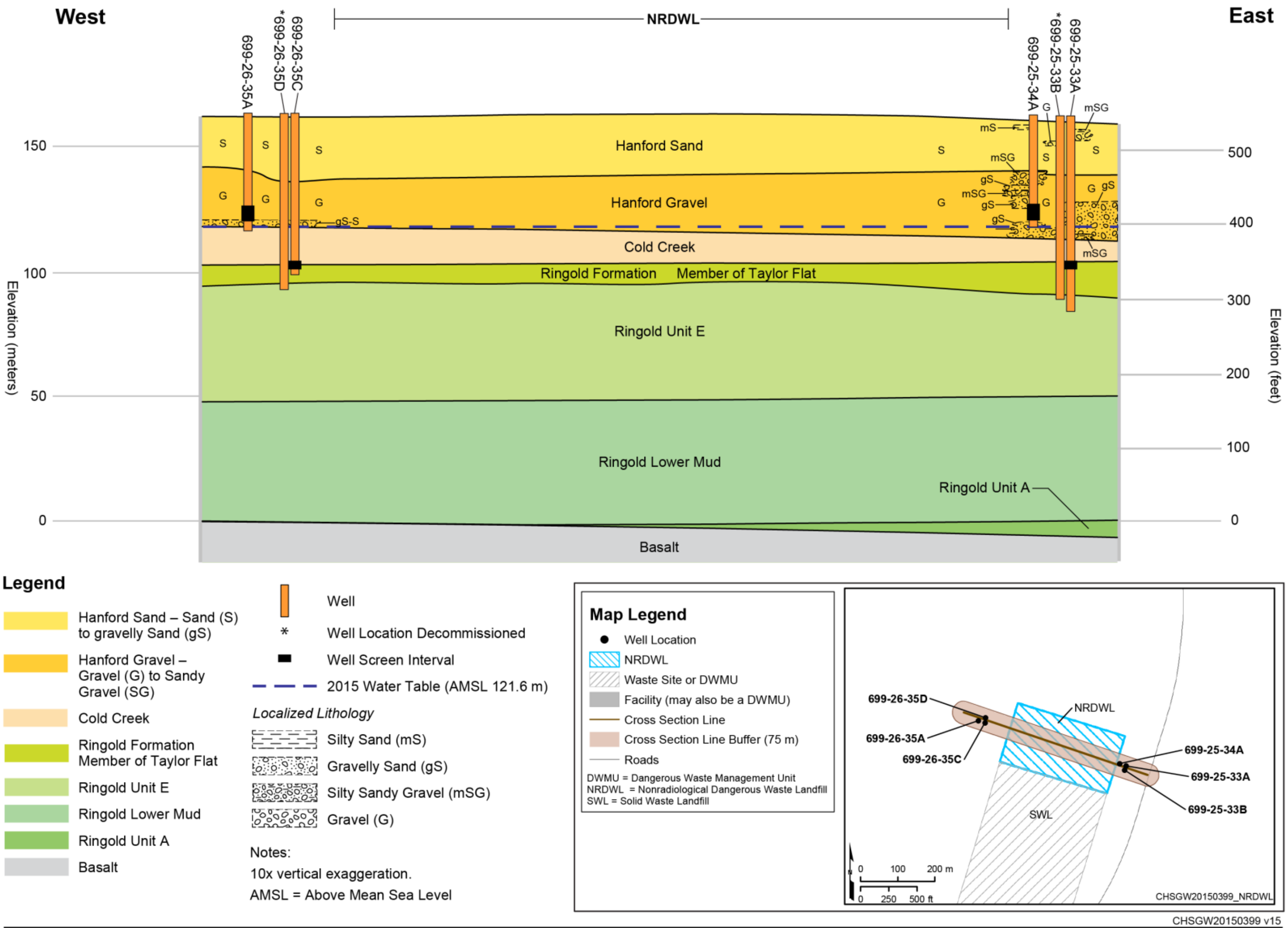


Figure 3-2. West to East Cross Section Showing Stratigraphy Underlying NRDWL

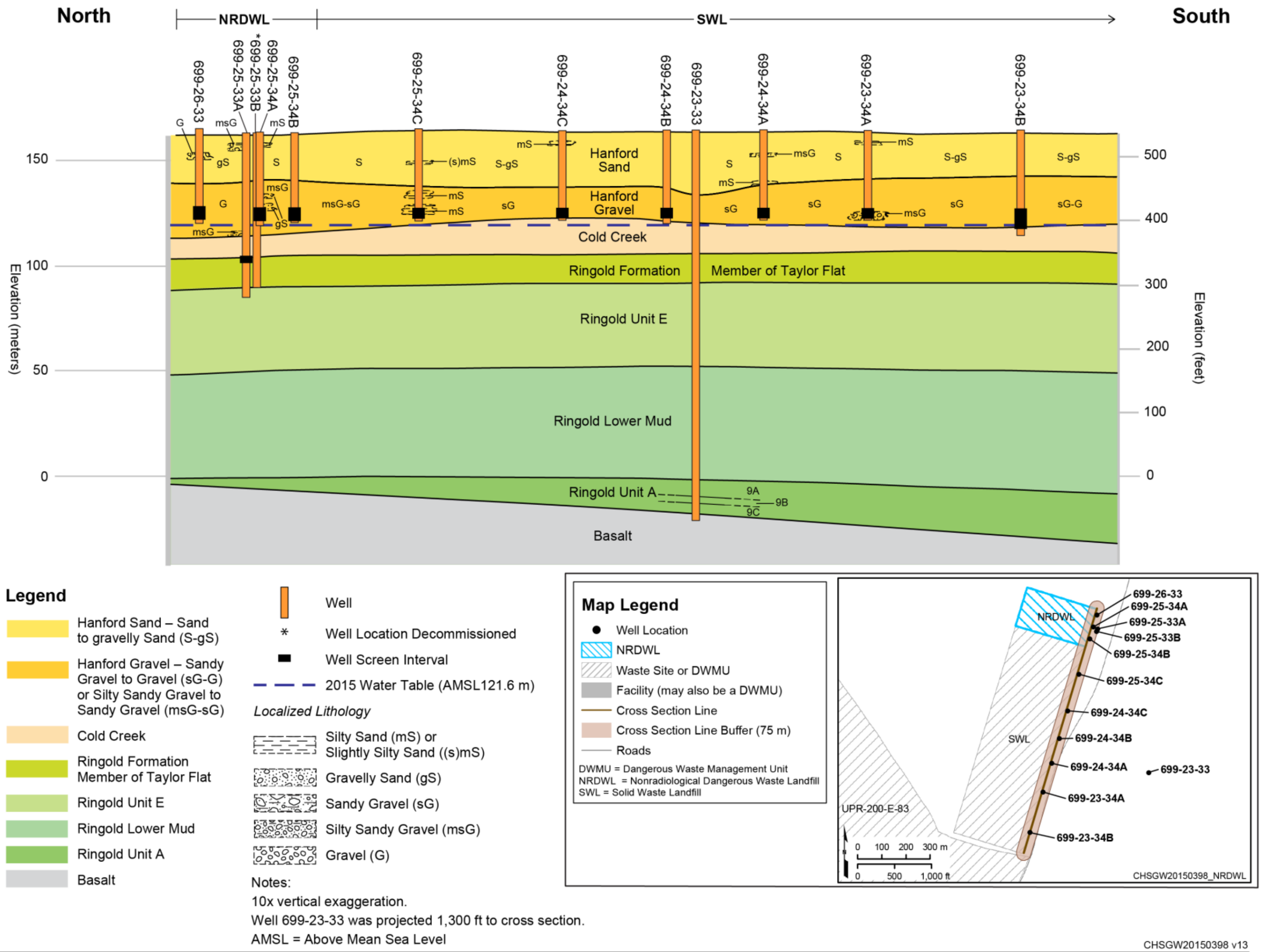


Figure 3-3. North to South Cross Section Showing Stratigraphy Underlying NRDWL

- The Rlm (equivalent to HSU 8) is composed of a sequence of fluvial overbank, paleosol, and lacustrine silt and clay, with minor sand and gravel (Section 3.4.2 in DOE/RL-2009-85). This unit may locally create confining conditions and isolate the Rwie from the underlying Rwia when all units are present and laterally continuous. Beneath NRDWL, the Rlm is expected to be approximately 42 m (138 ft) thick.
- The Rwia (equivalent to HSU 9) comprises the base of the Ringold Formation that unconformably overlies the basalt bedrock. This unit consists of silty sandy gravel deposits. Additionally, intercalated lenticular sand and silt of the fluvial sand and overbank facies associations have been encountered locally in the middle part of the Rwia (Section 4.2.1 in WHC-SD-EN-TI-012). The Rwia is thicker to the south and east of SWL and pinches out beneath SWL. The Rwia is expected to be encountered at 160 m (525 ft) below ground surface.
- Bedrock, consisting of Columbia River Basalt flows, dips gently to the south toward the axis of the Cold Creek syncline. The two uppermost flows are within the Elephant Mountain Member of the Saddle Mountains Basalt.

Geologic cross sections that include selected wells near NRDWL/SWL present the approximate stratigraphy underlying and adjacent to NRDWL (Figures 3-2 and 3-3). Geologic contacts associated with the wells presented in the cross sections are based on the contacts defined in Table A-2 of Attachment A within ECF-Hanford-13-0029, Rev. 1. Definition of the stratigraphic units and contacts shown in each cross section is consistent with the most current, integrated understanding of the subsurface geologic framework beneath the 200 East Area. In some cases, geologic contacts and stratigraphy from adjacent areas where data are available are projected to surrounding areas where data are less complete, utilizing the geologic three-dimensional software (ECF-Hanford-13-0029, Rev. 1). As indicated in each figure legend, geologic information associated with a well is projected to the cross section within a buffer zone extending 75 m (246 ft) from either side of the cross-section line, resulting in approximate depths for stratigraphic contacts.

3.2 Hydrogeology

The groundwater beneath NRDWL occurs as an unconfined aquifer and deeper, confined aquifers. The water table occurs within the gravel-dominated sequence of the Hanford formation (Figures 3-1, 3-2, and 3-3) and the gravel-dominated CCU, at an elevation of 121.5 m (398.6 ft). Based on the maximum surface elevations at NRDWL, the unsaturated thickness of the vadose zone is approximately 43.9 m (144 ft) thick. The uppermost aquifer is unconfined and comprises the saturated Hanford formation sediments, CCU_g, Rtf, and Rwie. The base of the unconfined aquifer is the top of the fine-grained Rlm unit, which is expected to be encountered at 118 m (387 ft) below ground surface. The lower, confined aquifer is considerably thinner than the unconfined aquifer beneath NRDWL, and there is no evidence of hydraulic connectivity between the two aquifers in the immediate vicinity of the site. Confined zones in the basalt aquifers are present in sedimentary interbeds and/or interflow zones (i.e., networks of interconnecting vesicles and fractures) that occur between dense basalt flows (Section 2.3 in RHO-RE-ST-12P, *An Assessment of Aquifer Intercommunication in the B Pond-Gable Mountain Pond Area of the Hanford Site*) beneath the Central Plateau. There is no evidence of confined basalt and unconfined aquifer communication in the vicinity of NRDWL.

The average hydraulic conductivity of the uppermost unconfined aquifer is a composite of these units and is estimated at 520 to 1,500 m/d (1,710 to 4,920 ft/d) (Section 5.3.2 in WHC-EP-0021). A low-permeability lithologic sequence identified in the Rtf (HSU 4) (Figure 3-1) appears to locally restrict vertical hydraulic connectivity within the unconfined aquifer because its hydraulic conductivity is orders of magnitude lower than the overlying or underlying sediments (Section 5.2 in WHC-EP-0021 and Section 5.3.5 in DOE/RL-90-17). The sequence contains a thin interval of hard, clayey silt that is approximately 2 m (7 ft) thick on the east side of NRDWL, approximately 4 m (16 ft) thick on the west side of NRDWL and approximately 3 m (10 ft) thick on the east side of SWL (Section 4.4.3.1.2 in WHC-EP-0021). Laboratory testing indicates that the vertical hydraulic conductivity of the clay interval is estimated to range from 0.00009 to 0.0006 m/d (0.0003 to 0.002 ft/d) (Section 5.3.2 in WHC-EP-0021). The low-permeability interval is believed to be continuous underlying the NRDWL and SWL area because it is noted in drilling logs from wells completed along both the east (699-25-33A) and west side (699-26-35D) of NRDWL (Figure 3-2) and 425 m (1,395 ft) east of SWL (699-23-33) (Figure 3-3). Two wells (699-26-35C and 699-25-33A) at NRDWL sample the portion of the aquifer just above the low-permeability interval. Hydraulic heads in these wells are virtually the same as in adjacent wells completed at the top of the aquifer, indicating very low to no vertical gradient in the unconfined aquifer (Section 3.7.2 in PNNL-12086, *Hanford Site Groundwater Monitoring for Fiscal Year 1998*).

Sandy gravel to gravel of the Rwie underlies the Rtf. The Rwie has a hydraulic conductivity of approximately 0.3 to 15 m/d (1 to 49 ft/d). The low-permeability interval within the Rtf may limit vertical groundwater flow and contaminant migration between overlying sediments and the underlying Rwie. The Rlm is below Rwie throughout much of the Hanford Site. Where present, the Rwia comprises the confined aquifer in the suprabasalt sediments, with the Rlm acting as an upper confining to semiconfining layer, separating the Rwia from the Rwie. The local presence of the Rlm is indicated based on stratigraphic correlations between offset wells in 200-PO-1 OU far-field area and modeled in the Hanford South Geoframework (ECF-HANFORD-13-0029, Rev. 5). The Columbia River Basalt Group underlies the Ringold Formation. Aquifers in the basalt are confined by the dense interiors of basalt flows.

3.3 Groundwater Flow System

During the defense operational efforts at the Hanford Site (1943 to 1995), the groundwater elevation and flow direction throughout much of the 200 East Area were influenced by the persistent hydraulic mounding associated with planned discharges in the 200 West Area and with planned discharges within and near the 200 East Area. These include large-volume discharges to the 216-B-3 Pond (B Pond) system (located on the east side of the 200 East Area), and Gable Mountain Pond (i.e., 216-A-25 Pond, located to the north of the 200 East Area). This groundwater mounding is evident in hydrographs and water table maps up to, through, and in some locations beyond the 1990s. Along the east and east-central part of the 200 East Area, the mounding generated a local hydraulic gradient to the southwest (Chapter 4 in SGW-60338, *Historical Changes in Water Elevation and Groundwater Flow at Hanford: 1944 to 2014*).

Water table elevations in the 200 East Area were at their highest during the Hanford Site's peak operating years (the 1960s through 1990s; Figure 2 in SGW-60338). The termination of discharges to the Gable Mountain Pond system in 1985, and subsequent termination of discharges to the B Pond system in 1993, resulted in the gradual dissipation of the 200 East Area groundwater mound. As groundwater elevations continued to decline, the water table became extremely flat throughout the 200 East Area. Because of the flat water table, it became difficult to estimate the direction of groundwater flow by measuring water levels and mapping the water table. Changes in groundwater elevations and associated hydraulic gradients and flow directions have become less discernible from year-to-year subsequent to the cessation of operational discharges. The changes in gradient magnitude have been accompanied by changes in groundwater flow direction, with most of the 200 East Area presently exhibiting a northwest to southeast flow direction. This flow direction suggests that the groundwater elevations and hydraulic gradients are approaching pre-operational conditions at the Hanford Site.

Data compiled in 2016 and used for trend surface analysis indicate an east-southeast flow direction and a hydraulic gradient of 3.1×10^{-5} m/m (10×10^{-5} ft/ft). This flow direction generally agrees with the southeast flow direction inferred from historical plume migration in this area and hydraulic head differences in the NRDWL/SWL area compared to the 200 East Area (Section 2.15 in DOE/RL-2016-66, *Hanford Site RCRA Groundwater Monitoring Report for 2016*).

Between 2011 and 2013 efforts, including vertical offset surveys of well casings, high-resolution water-level measurements, and consideration of barometric effects were implemented to improve the accuracy of the water-level measurements and resultant estimates of the groundwater gradient near NRDWL (Section 200-PO RCRA - NRDWL in DOE/RL-2014-32). The results of that evaluation indicated that the average hydraulic gradient from January 2011 to March 2013 was 3.3×10^{-5} m/m (10×10^{-5} ft/ft) and the flow direction was east-southeast. In 2014, the flow direction was southeast with a hydraulic gradient of 2.4×10^{-5} m/m (7.9×10^{-5} ft/ft) (Section 10.13.7.2 in DOE/RL-2015-07).

As described in Section 2.4.3 in DOE/RL-2017-19, the rate of groundwater flow beneath NRDWL was calculated to range from 0.12 to 0.37 m/d (0.39 to 1.21 ft/d), based on a hydraulic conductivity range of 518 to 1,524 m/d (1,699 to 5,000 ft/d) and an assumed effective porosity of 0.1. The water table directly beneath the NRDWL and SWL area is relatively flat, with an elevation ranging between 121.624 and 121.646 m (399.05 and 399.12 ft). The rate of water-level decline in the vicinity of SWL and NRDWL has decreased: between April 2010 and April 2015 water table elevations within SWL and NRDWL network wells decreased only about 0.13 m (0.43 ft) (Section 2.4.3 in DOE/RL-2017-19).

Figures 3-4 through 3-7 show the results of water-level mapping performed in the vicinity of NRDWL for calendar years 2013 through 2016. This water-level mapping forms the basis for the facility-specific calculations detailed in Chapters 5 through 7 of this report. As described in ECF-200PO1-18-0010, *Groundwater Flow and Migration Calculations to Support the Assessment of the NRDWL Groundwater Monitoring Network*, groundwater elevations were mapped based on comprehensive groundwater elevation datasets obtained for calendar years 2013, 2014, 2015, and 2016 in order to produce piece-wise continuous (gridded) depictions of groundwater elevations throughout the area surrounding NRDWL. Four years were evaluated because different yearly datasets can produce some differences in the interpretation of groundwater elevations and flow directions among years and among datasets. Groundwater-level mapping was performed using the multi-event universal kriging (MEUK) technique (Tonkin et al., 2016, "Multi-Event Universal Kriging [MEUK]"). MEUK is designed to create a series of related maps, each corresponding to a specific event but all of which can exhibit spatial relationships that persist over time. MEUK is discussed in more detail in Chapter 5. The water-level maps indicate consistent flow directions and hydraulic gradients toward the east and east-southeast throughout the four mapped years.

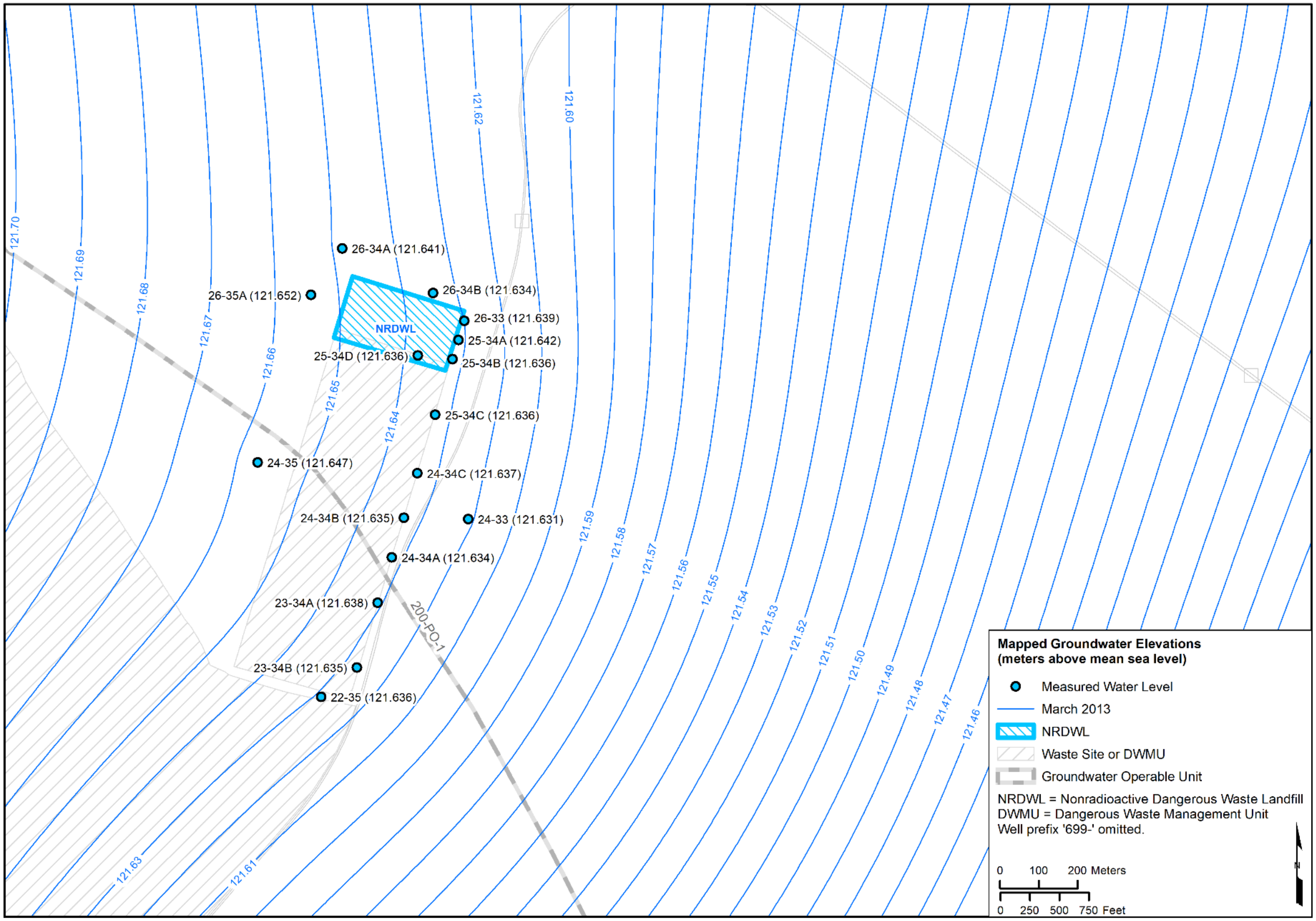


Figure 3-4. Groundwater Elevation Map for NRDWL, 2013

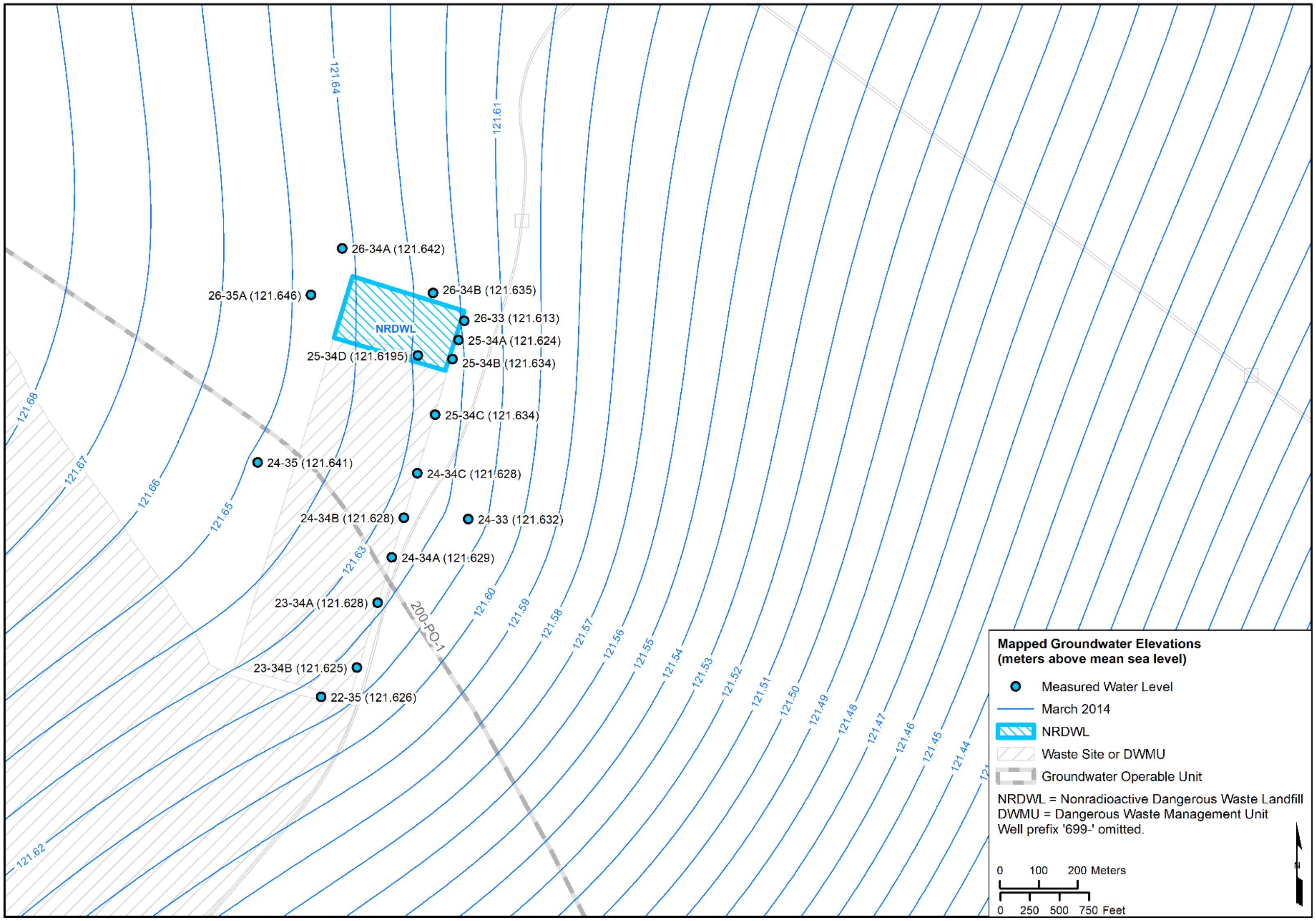


Figure 3-5. Groundwater Elevation Map for NRDWL, 2014

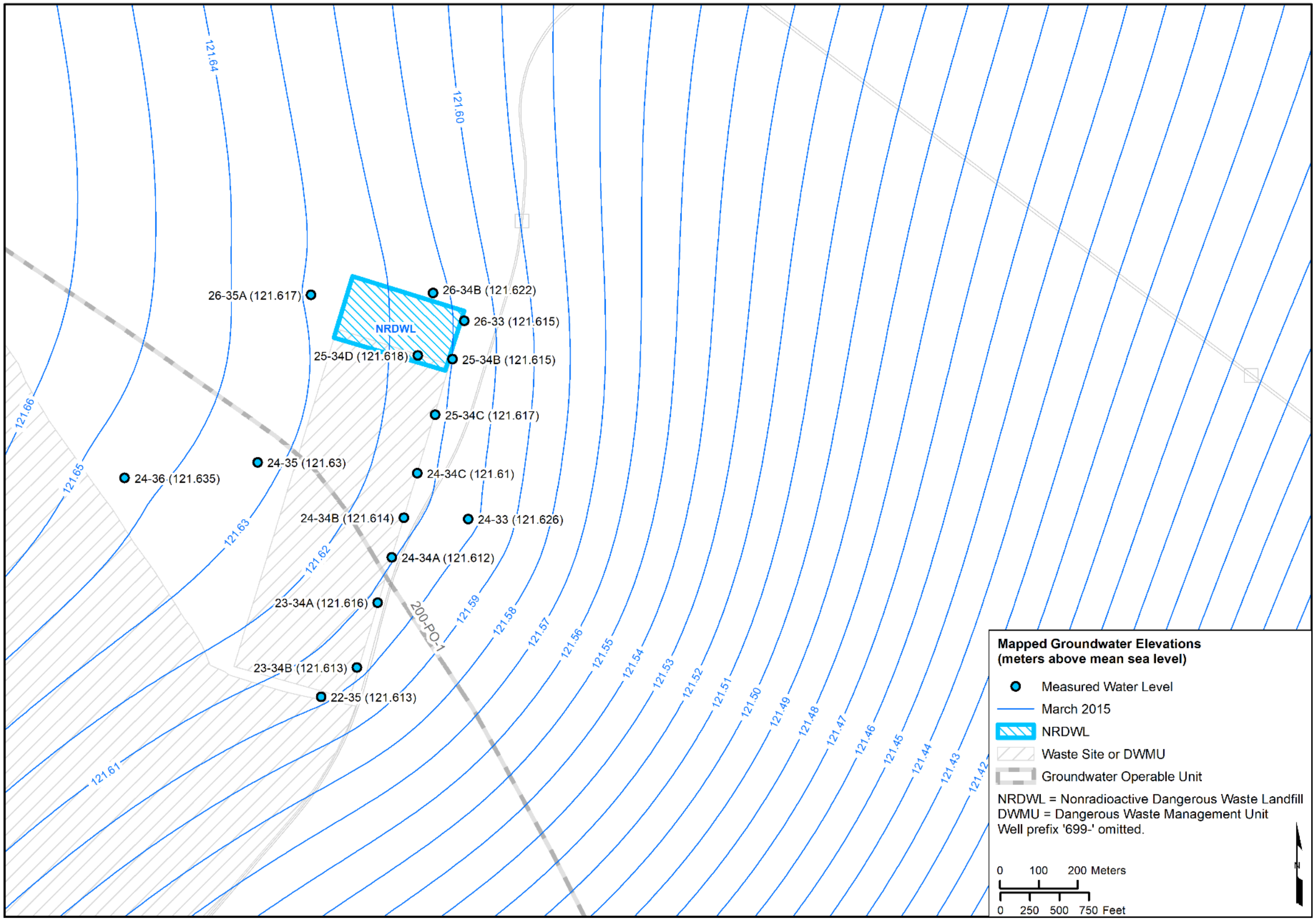


Figure 3-6. Groundwater Elevation Map for NRDWL, 2015

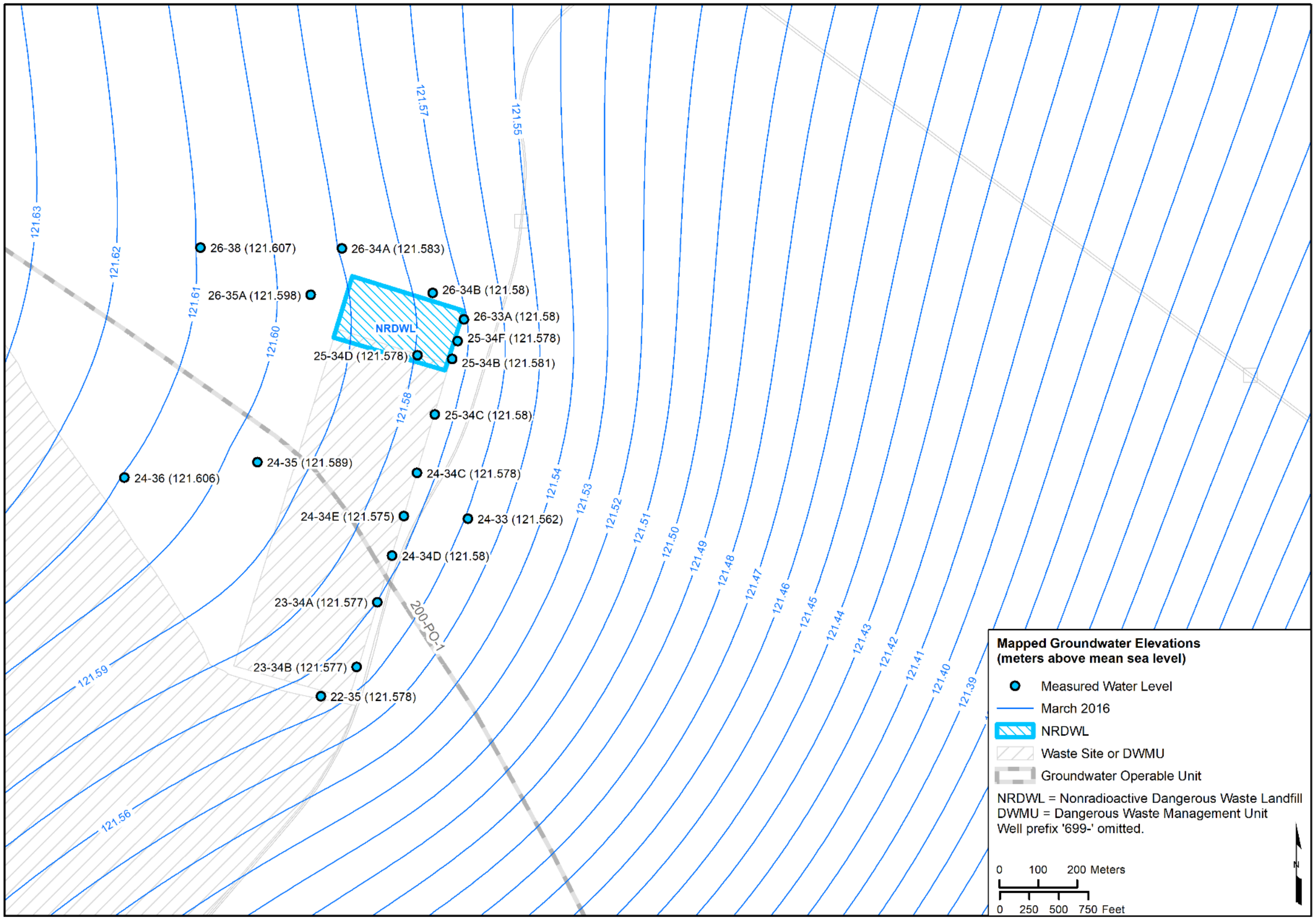


Figure 3-7. Groundwater Elevation Map for NRDWL, 2016

4 Contaminant Migration Conceptual Model

The conceptual model for contaminant release and transport through the vadose zone to groundwater, summarized in the following sections, is based on following assumptions listed below. The influence of the adjacent SWL is included in this discussion because of its potential effect (i.e., via transport by soil gas) on soil and groundwater beneath NRDWL. Data and analyses presented in several previous studies associated with NRDWL and SWL are documented and further discussed in Section 2.6 in DOE/RL-2017-19.

- Average precipitation of about 16 cm/yr (6.3 in./yr) and net infiltration of 10 to 20 mm/yr (0.39 to 0.79 in./yr) prevail over the timeframe of interest (operational lifespan and post-closure monitoring period) (Figures A.3 and 1.2 in PNL-10285, *Estimated Recharge Rates at the Hanford Site*).
- Leaching of mobile contaminants from buried waste in damaged/degraded sealed containers or contaminated soils in direct contact with the trench is assumed to be the major potential source for contamination to enter the vadose zone.
- Soil-gas surveys performed at the site have shown the presence of DNAPLs. In the vadose zone, DNAPLs can volatilize to the vapor phase or dissolve into the soil moisture (aqueous phase) and generally leave residual contamination in zones through which they have migrated. Limited DNAPL transport to the groundwater via infiltrating precipitation is possible at NRDWL.
- Carbon dioxide from the breakdown of raw sewage at the site is likely responsible for significant increases in specific conductance concentrations in groundwater.
- Artificial sources of water (e.g., leaking potable or raw water lines) are not present based on Hanford Site drawings.
- Extreme conditions or accidental releases are recognized as factors but would be addressed under emergency response/corrective actions.

4.1 Vadose Zone

The vadose zone beneath NRDWL is approximately 43.9 m (144 ft) thick and consists primarily of the Hanford formation (Figure 3-2). The water table exists in the lowest portion of the Hanford formation and upper portion of CCU_g.

The vadose zone was impacted primarily by sewage from chemical toilets and 1100 Area catch tank liquid that were discharged to the liquid waste trenches at SWL (Section 3.4.4 in DOE/RL-2010-28). It is possible that the vadose zone may be impacted by the small quantities of liquid waste in drums or laboratory packs with surrounding absorbing material that were previously placed in NRDWL (Section 3.4.4 in DOE/RL-2010-28).

Per Section 3.4.4 in DOE/RL-2010-28, "The total quantity of liquid waste discharged to the liquid waste trenches at SWL was 4.18 to 6.08 million L (4,180 to 6,080 m^3, or 1.1 to 1.6 million gal) over a 12-year period from 1975 to 1987. The volume of pore space beneath the SWL trenches (to the water table) is estimated to be 26,380 m^3 (6,968,859 gal), assuming 25% pore space in the vadose zone sediment (2,638 m^2 [28,395 ft^2] for the area of the liquid waste trenches and 40 m [131 ft] to the water table). Thus, the volume of waste is approximately 6,000 m^3 (1,585,032 gal), and the available pore space is approximately 26,000 m^3 (6,868,473 gal). Because the total volume of wastewater is less than one-fourth of the available pore volume beneath the SWL liquid waste trenches, it is unlikely that liquid waste discharges migrated to the water table as saturated flow."

4.1.1 Soil Vapor Movement and Distribution

Soil vapor surveys conducted in 1993 and 1997 at shallow and deep depths in the vadose zone beneath NRDWL and SWL indicated the presence of TCA, 1,1-dichloroethane, PCE, TCE, carbon tetrachloride, and chloroform within and south of the eastern third of the NRDWL trenches (Executive Summary in BHI-01115, *Evaluation of the Soil-Gas Survey at the Nonradioactive Dangerous Waste Landfill*, and Chapter 1 in WHC-SD-EN-TI-199, *Nonradioactive Dangerous Waste Landfill Soil-Gas Survey: Final Data Report*). Based on the results of the 1997 soil-gas survey, Chapter 5 in BHI-01115 concluded that the soil vapor VOCs tended to be distributed at low concentrations within or south of the NRDWL trenches. Soil vapor concentrations of TCA tended to be higher with increasing depth. Soil vapor concentrations of PCE generally tended to be lower with increasing depth. The highest concentrations of carbon tetrachloride and chloroform were localized, detected in the shallow and deep samples within and beneath the chemical trenches (Chapter 5 in BHI-01115). BHI-01115 (Figures 13 through 19 in BHI-01115) noted that the concentrations of those VOCs detected during the soil-gas survey had generally decreased in NRDWL groundwater monitoring wells between 1992 and 1996. The BHI-01115 study indicated that carbon tetrachloride was the only VOC detected in the soil gas that was of potential concern with regard to groundwater quality (Chapter 5 in BHI-01115). However, detections of carbon tetrachloride in groundwater samples collected between 1991 and 1996 were sporadic and difficult to attribute to a particular point source.

In 1988 and 1989, soil-gas sampling at the adjacent SWL detected TCA, PCE, and TCE in shallow soil-gas probes as far as 115 m (377 ft) east and 130 m (427 ft) west beyond the SWL fence (Table 1 in PNL-7147, *Final Report: Soil-Gas Survey at the Solid Waste Landfill*). Subsequent to this initial soil-gas survey, in parallel with the soil-gas analysis completed in 1997 at NRDWL (BHI-01115), a detailed evaluation of all available soil-gas and groundwater data at SWL was conducted and reported in BHI-01063, *Conceptual Model for the Solid Waste Landfill*. The report included results from 1993 through 1997 for the permanent soil-gas monitoring stations that had been installed around the perimeter of SWL, and between SWL and NRDWL. BHI-01063 (Chapter 4) noted that for SWL, the same four VOCs detected in soil gas (TCA, 1,1-dichloroethane, PCE, and TCE) had also been consistently detected in downgradient groundwater monitoring wells at SWL since 1997. Chlorinated solvents have relatively high vapor pressures, so they can readily partition to a vapor phase and migrate in the vadose zone (Chapter 4 in BHI-01063). As stated in Chapter 5 of BHI-01063, "The contaminants of concern are all volatile and soluble chemicals that can partition into aqueous and vapor phases. In the vapor phase, the contaminant can be transported in the vadose zone through diffusion or through advective flow driven by pressure gradients caused by fluctuations in barometric pressure ("barometric pumping"). The vapor can migrate out of the vadose zone in all directions, including 'upgradient' relative to groundwater flow." Contaminants beneath SWL may migrate to the subsurface of NRDWL.

Based on their detection in downgradient groundwater wells, the primary contaminants at NRDWL in 1997 were TCA, DCA, PCE, TCE, carbon tetrachloride, and chloroform. As organic liquids, these compounds are referred to as DNAPLs because they are denser than water and exhibit low absolute solubility in water. In general, chlorinated solvents have relatively high vapor pressures, so they can readily partition to a vapor phase and migrate great distances in the vadose zone (Section 2.6.3 in DOE/RL-2017-19). DNAPL liquids in the vadose zone can volatilize to the vapor phase or dissolve into the soil moisture (aqueous phase), and generally leave residual contamination in zones through which they have migrated. Soil that is saturated with a pure liquid DNAPL will have an associated equilibrium vapor concentration. The low vapor concentrations observed during soil gas surveys and at perimeter monitoring stations around the SWL and between NRDWL and the SWL (less than 1/100th of the equilibrium value) suggest that pure phase DNAPLs are not present (although the presence of this phase cannot be conclusively ruled out) (Section 2.6.4 in DOE/RL-2017-19). Soil-gas sampling continues at

SWL at select locations. Low levels of methane, carbon dioxide, methylene chloride, 1,1-dichloroethane, chloroform, TCA, carbon tetrachloride, TCE, and PCE were detected in 2017 (Table 8 in DOE/RL-2015-21, *Hanford Site Solid Waste Landfill Annual Monitoring Report October 2016 Through September 2017*).

4.2 Soil Moisture Factors

During the operating period of the landfill before it was filled in, direct precipitation contacting waste materials exposed to the atmosphere was the primary driver for hypothetical leaching of waste constituents to the vadose zone. After the operational lifespan of NRDWL is complete, the texture and structure of the backfill and the amount of vegetative cover will tend to reduce the amount of natural infiltration reaching the waste.

Because of the highly transmissive nature of the Hanford formation beneath the site, there are no natural geologic barriers to vertical contaminant transport from the vadose zone beneath the site to the water table (Section 3.2). Under the gravity drainage assumption, lateral spreading of infiltrated water is likely to be minimal.

It is estimated that recharge rates in the portion of the 200 East Area in the vicinity of NRDWL range from 4 mm/yr (0.17 in./yr) in a shrub-steppe vegetated area to 44 mm/yr (1.7 in./yr) at a gravel-covered, nonvegetated site (Table 4.14 in PNNL-14702, *Vadose Zone Hydrogeology Data Package for Hanford Assessments*).

Present conditions beneath the landfill reflect unsaturated flow conditions in the vadose zone driven primarily by natural infiltration of meteoric water. There is no current injection of water into the vadose zone in the vicinity of the trenches, and none is anticipated. Hypothetical release of leachate from the trenches would result in unsaturated flow through the vadose.

4.3 Hydrogeologic Considerations

Water levels in the uppermost unconfined aquifer have risen as much as 9 m (30 ft) beneath the 200 East Area because of artificial recharge from liquid waste disposal operations since the mid-1940s (Table 1 in SGW-60338, and Section 3.2 in PNNL-15837, *Data Package for Past and Current Groundwater Flow and Contamination Beneath Single-Shell Tank Waste Management Areas*). The largest volumes of discharge were to the B Pond system east of the 200 East Area, the 216-A-25 (Gable Mountain) Pond system north of the 200 East Area, and several of the PUREX Plant cribs to the north and west of NRDWL. The Gable Mountain pond system is estimated to have received approximately 293 billion L (77 billion gal) of effluent and B Pond to have received about 256 billion L (68 billion gal) of effluent. These large volumes disposed to the ponds (and lesser volumes to cribs and ditches) artificially recharged the unconfined aquifer, creating large water table mounds. The increase in water table elevation was most rapid from 1954 to 1963. The water table declined somewhat in the late 1960s and early 1970s, then increased again in the early 1980s before a final decline throughout the 1990s when wastewater discharges in the 200 East Area were reduced (Section 8.2.2.1 in RPP-23748, *Geology, Hydrogeology, Geochemistry, and Mineralogy Data Package for the Single-Shell Tank Waste Management Areas at the Hanford Site*). In the 1980s, the groundwater mound in the area was maintained by liquid discharge to B Pond to the north and west of NRDWL.

The configuration of the 200 East Area water table at any given time results from fluctuations in boundary conditions related to Columbia River stage and hydraulic effects related to discharges to the Treated Effluent Disposal Facility (TEDF), located southeast of the 200 East Area. Discharges to TEDF are variable, consisting primarily of steam condensate and noncontact cooling water. The normal pattern of discharge is a low-volume background, averaging 6.7 million L/month (1.8 million gal/month) (2011 through 2013), with occasional discharge volumes in excess of 100 million L/month (26 million gal/month) that occur when the 242-A Evaporator is operating. These larger discharges affect the 200 East Area water table. During 2016, high-volume discharges to TEDF occurred in April with a total of 277 million L (73 million gal) (Section 10.2 in DOE/RL-2016-67, *Hanford Site Groundwater Monitoring Report for 2016*). However, discharges to TEDF were not great enough to cause the groundwater flow direction to change, and flow continued toward the southeast during 2015 and 2016. The main effect of TEDF discharges has been to reduce gradient toward the southeast (Section 10.2 in DOE/RL-2016-67), mainly in the 200 East Area.

Between April 2010 and April 2015, water table elevations within SWL and NRDWL network wells have shown a decrease of only about 0.13 m (0.43 ft) (Section 2.4.3 in DOE/RL-2017-19), or an average rate of water-level decline of 0.026 m/yr (0.085 ft/yr).

A low-permeability lithologic sequence identified in the Rtf (HSU 4) appears to locally restrict vertical hydraulic connectivity within the unconfined aquifer because its hydraulic conductivity is orders of magnitude lower than the overlying or underlying sediments (Section 3.2). Silty sand to sandy gravel of the Rwie underlies the Rtf. The low-permeability interval within the Rtf may limit vertical groundwater flow and contaminant migration between overlying sediments and the underlying the Rwie (Section 3.2).

4.4 Groundwater Chemistry

The solubility and subsequent mobility of waste constituents in pore fluid depend on the chemical nature of the waste constituents, the volume of water and water contact time with the waste, and natural subsurface geochemical conditions.

Pore fluid and groundwater in the unsaturated and saturated zones beneath NRDWL is slightly alkaline ($7<pH<9$), with appreciable amounts of bicarbonate and very little natural organic material. Vadose soil and groundwater are generally well aerated. The dissolved oxygen concentrations fall into the higher range for groundwater (7 to 10 mg/L). These general conditions favor sorption or retardation of many heavy metals (e.g., lead) and also favor stability of oxy-anionic species, which enhance mobility for other metals (e.g., hexavalent chromium). Laboratory sorption studies have documented these effects and related mobility conditions in Hanford Site media. These conditions tend to allow chlorinated solvents (e.g., carbon tetrachloride) to remain persistent, as these compounds normally degrade more rapidly in reduced groundwater environments.

Regional groundwater contaminant sources are identified through *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) remedial investigation activities at the 200-PO-1 OU in the 200 East Area. Monitoring results for the 200-PO-1 OU have shown that historically, the groundwater beneath much of 200 East Area has been contaminated from other sources, including the 200 East Area tank farms and the trenches, ditches, and ponds associated with Plutonium-Uranium Extraction Facility operations (Central Plateau in the Executive Summary of DOE/RL-2016-67).

4.4.1 Carbon Dioxide and Specific Conductance

Specific conductance at NRDWL and SWL rose steadily between 1990 and 2004, but stabilized or showed a slightly decreasing trend from 2005 to 2014 (Section 2.6.5 in DOE/RL-2017-19). Values at upgradient and downgradient wells are higher at SWL than at NRDWL (Figure 4-1). In October 2016, results for specific conductance in well 699-25-34B (which were consistent with historic values at the well) exceeded the critical mean and were consistent with historic values in well 699-25-34B (Section 2.15 in DOE/RL-2016-66). Higher concentrations of alkalinity, calcium, magnesium, specific conductance, and sulfate are measured in groundwater from wells at SWL compared to wells at NRDWL.

Time-series plots for these constituents at downgradient wells show higher concentrations at SWL well 699-24-34B and the lowest concentrations at NRDWL wells 699-26-33 and 699-25-34F (Section 2.6.5 in DOE/RL-2017-19; Figure 4-1). The concentration gradients of specific conductance at NRDWL and SWL as of October 2016 are shown on Figure 4-2. The elevated levels of alkalinity and specific conductance at NRDWL and SWL appear to be the result of increased levels of carbonate or bicarbonate in the groundwater ("Major Ions" in 01-GWVZ-025). The increased carbonate concentration is the result of high carbon dioxide concentrations in the vadose zone as initially observed in PNL-7147 (p. 17). The elevated carbon dioxide concentrations in the vadose zone beneath SWL apparently are the results of sewage breakdown under oxidizing conditions. Carbon dioxide typically comprises 40% to 60% of landfill gases. The major effect of an increase in carbon dioxide gas is an increase in the hardness of the groundwater (e.g., calcium carbonate), which could also be responsible for raising the specific conductance (Section 5.3.5.2 in DOE/RL-93-88). The source of high specific conductance is primarily calcium, bicarbonate, magnesium, and sulfate, which are nondangerous constituents (Section 2.6.5 in DOE/RL-2017-19).

4.4.2 Groundwater Quality Assessment Monitoring

In 2017, NRDWL entered a groundwater quality assessment program (DOE/RL-2017-19) that utilized the same monitoring network as the indicator parameter monitoring plan (DOE/RL-2015-32). Quarterly sampling for the assessment began in April 2017 and included the waste constituents in Appendix 5 of Ecology Publication 97-407.

A first determination report for the groundwater quality assessment sample results will incorporate an evaluation of the sample data. When completed, the first determination report will identify any dangerous wastes present in groundwater that are attributable to NRDWL.

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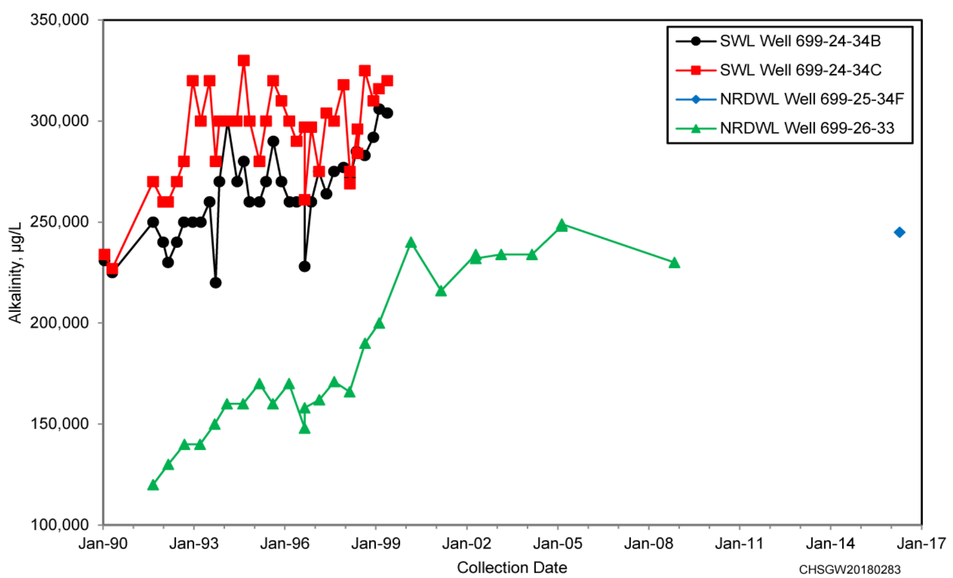
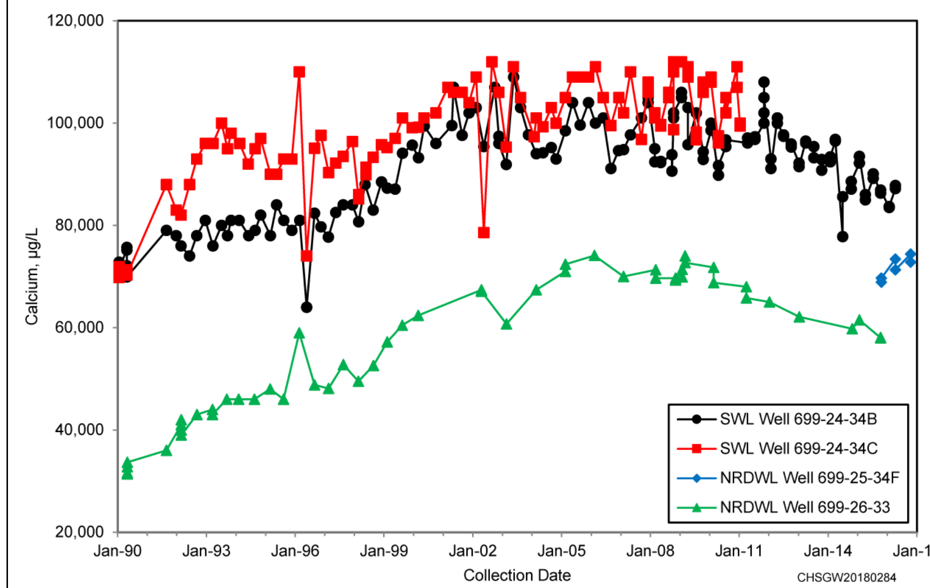
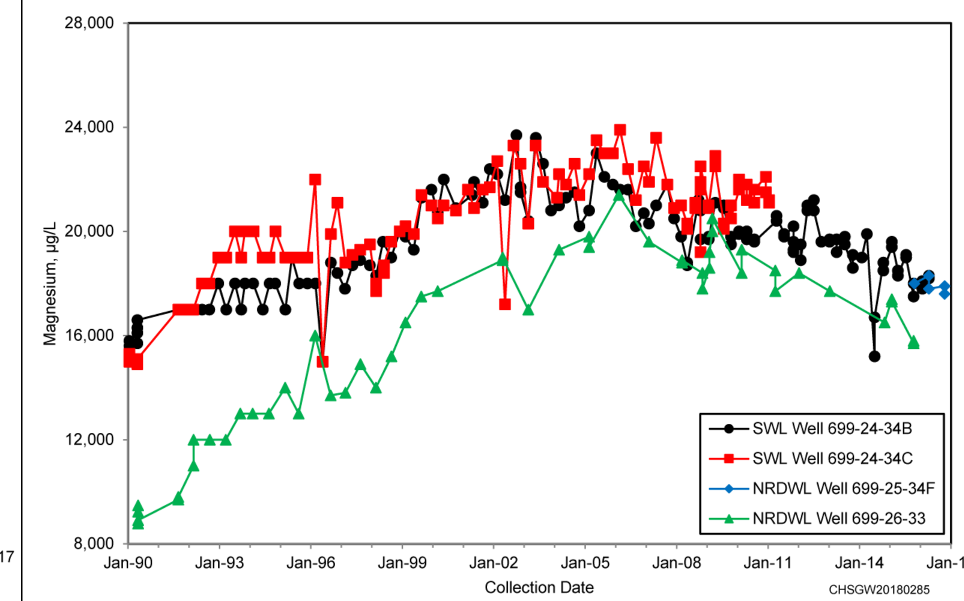
Alkalinity Concentration Trending from 1990 to 2016 for SWL and NRDWL Downgradient Wells



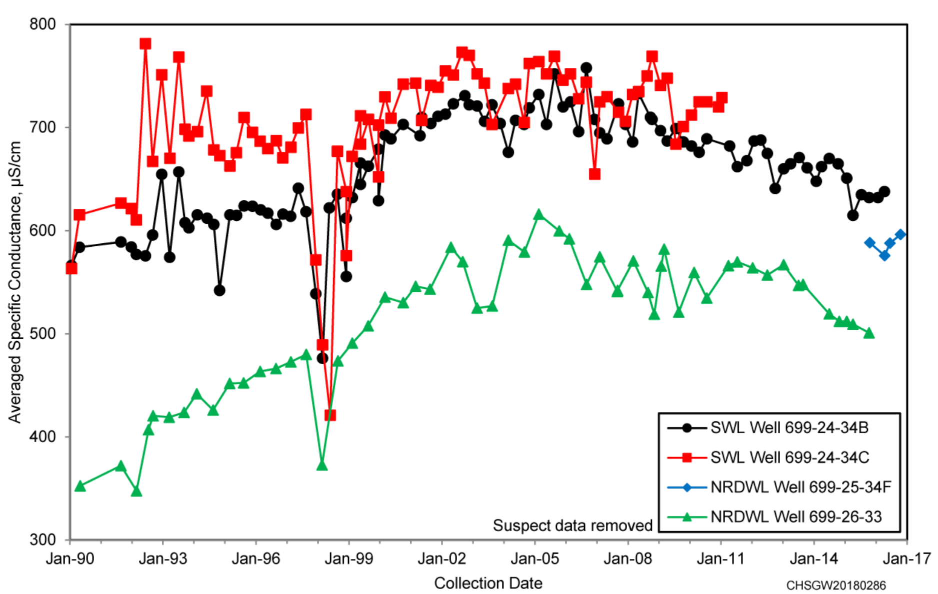
Calcium Concentration Trending from 1990 to 2016 for SWL and NRDWL Downgradient Wells



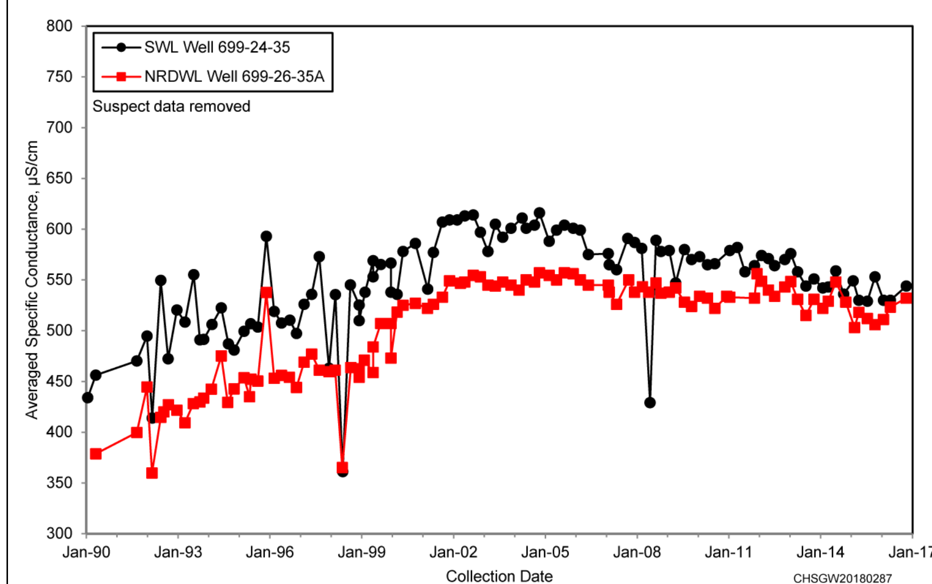
Magnesium Concentration Trending from 1990 to 2016 for SWL and NRDWL Downgradient Wells



Specific Conductance Concentration Trending from 1990 to 2016 for SWL and NRDWL Downgradient Wells



Specific Conductance Concentration Trending from 1990 to 2016 for SWL and NRDWL Upgradient Wells



Sulfate Concentration Trending from 1990 to 2016 for SWL and NRDWL Downgradient Wells

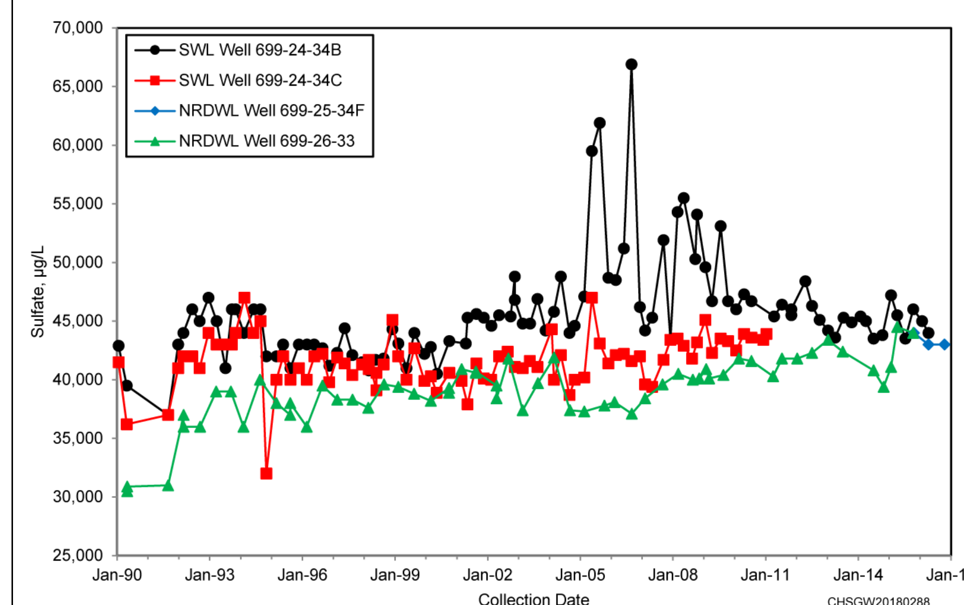


Figure 4-1. Time-Series Trend Plots of Alkalinity, Calcium, Magnesium, Specific Conductance, and Sulfate for NRDWL Versus SWL Wells

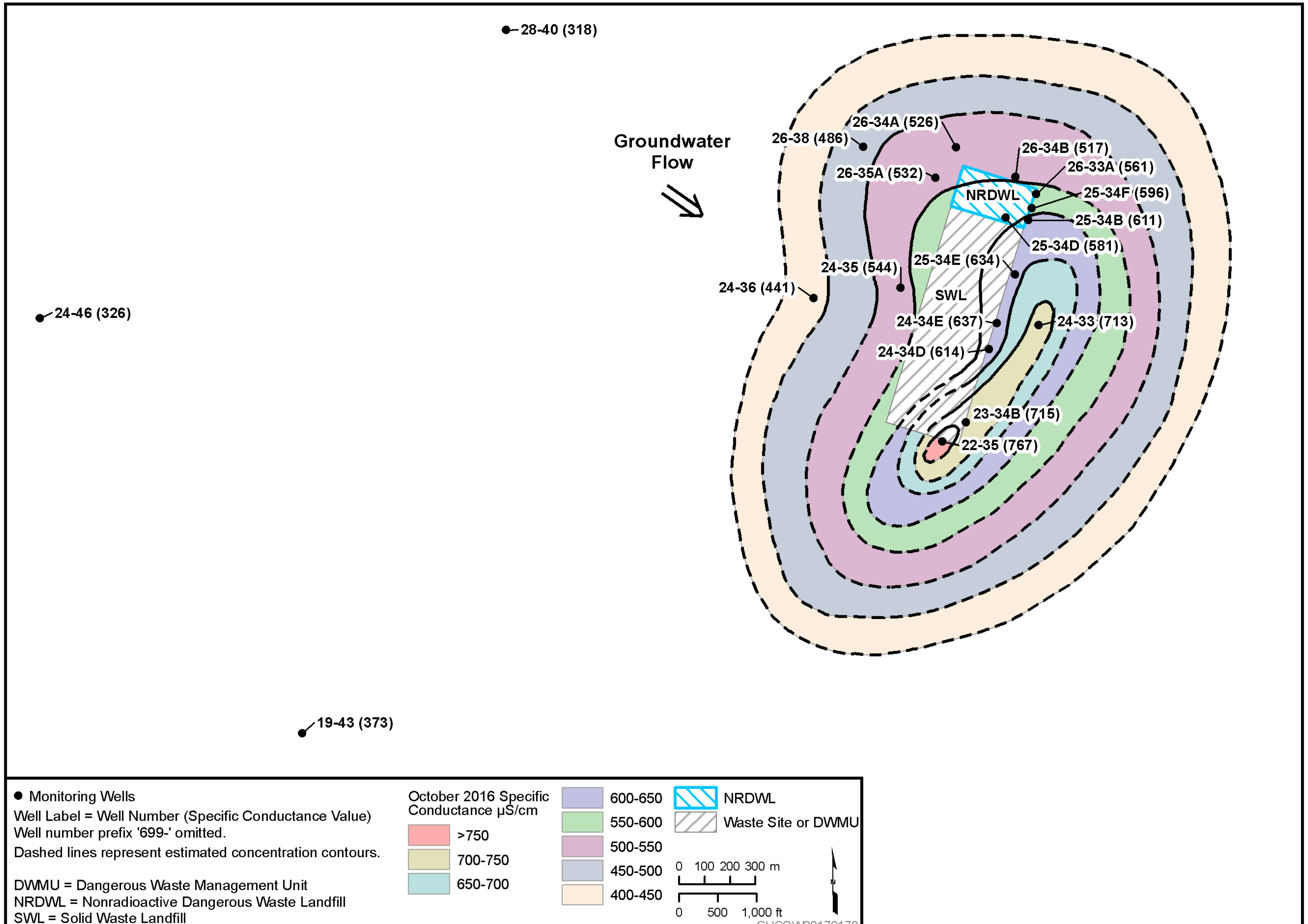


Figure 4-2. October 2016 Specific Conductance Concentration Gradients at NRDWL and SWL

5 Calculation Methods

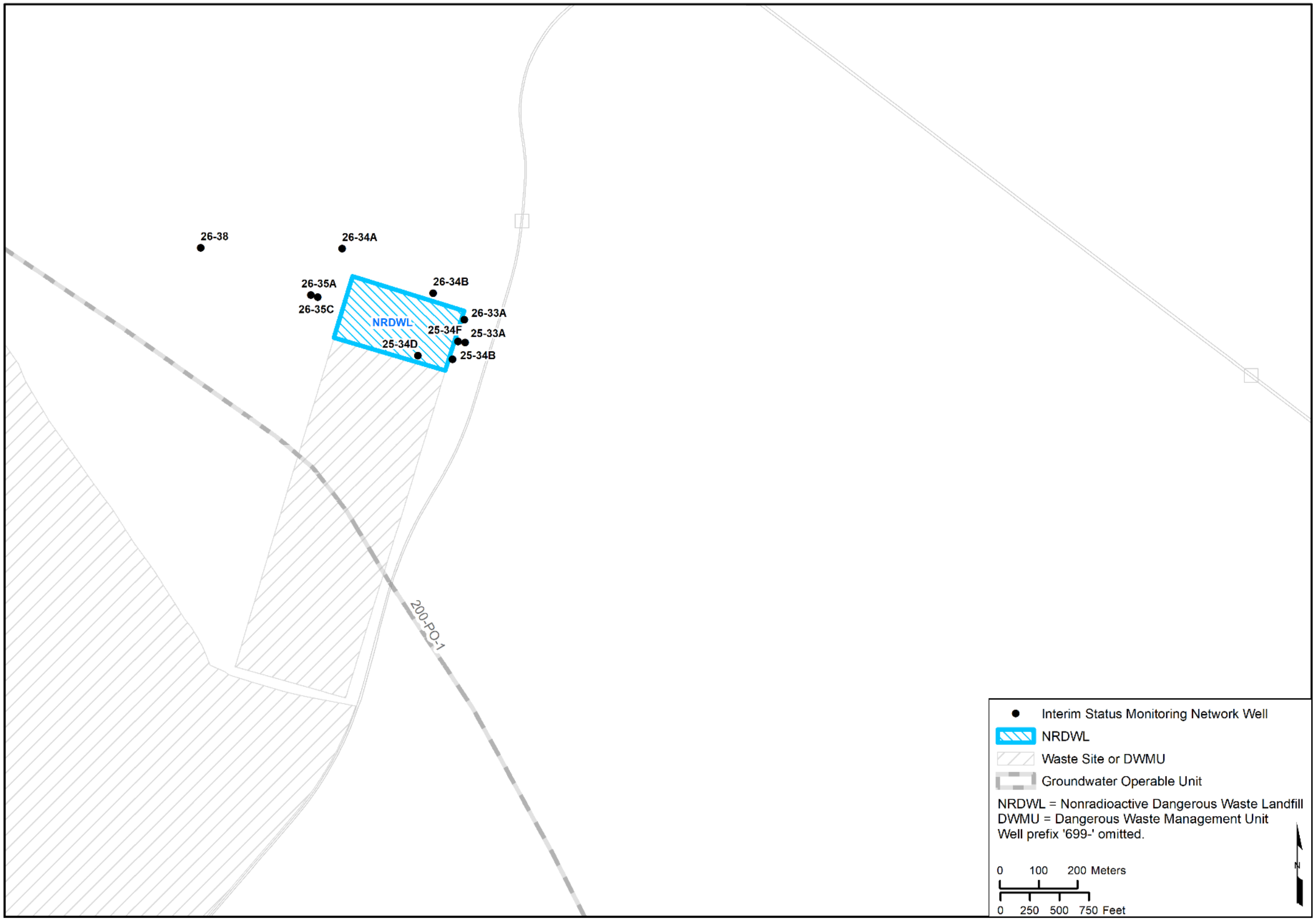
A systematic series of calculations was performed to evaluate whether the interim status groundwater monitoring wells for NRDWL (Figure 5-1) likely would detect increases in concentrations of contaminants in groundwater arising from potential releases from NRDWL that reach the underlying water table. The modeling effort was aimed at potential future releases and is not intended to address the effects of pre-existing contamination. The interim status monitoring network for NRDWL that was evaluated is described in Table 3-2 of DOE/RL-2017-19. The network consists of three upgradient wells (699-26-34A, 699-26-35A, and 699-26-38), two deep wells (699-25-33A and 699-26-35C), two crossgradient wells (699-25-34D and 699-26-34B), and three downgradient wells (699-25-34B, 699-25-34F, and 699-26-33A).

5.1 Method Selection

Two three-dimensional groundwater models were previously developed for fate and transport and remedy design purposes primarily associated with CERCLA. Together, these two models cover the entire Central Plateau. These models are the Central Plateau Groundwater Model (CPGWM) (CP-47631, *Model Package Report: Central Plateau Groundwater Model, Version 8.4.5*) and the Plateau to River (P2R) Model (CP-57037, *Model Package Report: Plateau to River Groundwater Transport Model Version 7.1*). In addition to these two models, a regularized inverse interpolation technique that is referred to as the Tikhonov Regularized Inverse Method (TRIM) was developed to obtain groundwater elevation maps to support engineering studies and evaluate DWMU monitoring networks within the 200 East Area (ECF-200E-18-0066, *Groundwater Flow and Migration Calculations to Assess Monitoring Networks in the 200 East Area Dangerous Waste Management Units*).

Although the CPGWM encompasses most of the Central Plateau, it was developed primarily to support decisions regarding the 200-ZP-1 and adjacent 200-UP-1 Groundwater OU remedies located in the 200 West Area. The CPGWM is the principal computational tool used to design and evaluate the performance of those groundwater remedies. Within the 200 West Area of the Central Plateau, the CPGWM specifically is being used to support engineering studies and reports because a predictive tool is needed to assess the impact of changing operations of the 200-ZP-1 groundwater pump and treat (P&T) system on directions and rates of groundwater flow and contaminant migration and on the efficacy of the interim status monitoring networks. In addition, the CPGWM was designed explicitly to simulate the effects of the 200-ZP-1 P&T remedy, which will be the single greatest influence on directions and rates of groundwater flow and contaminant migration in the 200 West Area for the next 20 or more years. The CPGWM was not designed to make predictions in the region of NRDWL, which is located in the far southeast corner of the CPGWM domain.

The P2R Model, which encompasses the entire 200 East Area and extends to the Columbia River, was developed primarily to support assessments of fate and transport throughout that area and decisions made under CERCLA for the 200 East Area. The P2R Model is not designed to make predictions at the scale of individual waste sites either within the 200 East Area or in the region of NRDWL. The P2R Model was developed at a large scale and using a coarse spatial discretization that is relevant to regional (i.e., far-field) rather than facility-specific (i.e., near-field) analyses. Facility-specific analyses that have previously been performed on the basis of the P2R Model were undertaken by developing local-scale facility-specific groundwater models extracted from the P2R Model using the method of telescopic mesh refinement. If the P2R Model were to be used to support analyses in the area of NRDWL, this would have to be similarly accomplished via the development of a local-scale facility-specific model.



Source: Table 2-55 in DOE/RL-2016-66, *Hanford Site RCRA Groundwater Monitoring Report for 2016*.

Figure 5-1. Interim Status Groundwater Monitoring Network

In the area near NRDWL, at the present time (2018) there is no wide-area P&T system or other groundwater remedy that will affect the rates and directions of groundwater flow and contaminant migration and none is anticipated for the foreseeable future. This eliminates the need for a predictive groundwater model that is capable of running predictive simulations representing the impacts to groundwater flow and contaminant migration from alternative potential operations of a large groundwater remedy such as the 200 West P&T.

Furthermore, the analysis of monitoring networks in the 200 East Area focuses on the uncertainty produced by the relatively low hydraulic gradients in the region. While the existing large-scale groundwater models meet the objectives of their development and are suited to their purposes, on a facility-specific scale, in some parts of the 200 East Area, both the CPGWM and P2R Model do not always reflect understanding of subtle near-field groundwater conditions based on multiple lines of evidence, including the low-gradient network and independent evaluations of existing contaminant extents and migration. For this reason, within the 200 East Area, TRIM was used to develop groundwater elevation maps for the assessment of groundwater monitoring networks.

NRDWL, although located on the Central Plateau, is not part of the 200 Areas and is located beyond (downgradient of) the other Central Plateau facilities in an area of comparatively uniform (planar) groundwater flow and potential contaminant migration that is relatively unaffected by the presence of HSU transitions and basalt or mud sub-cropping. The largely uniform gradient directions exhibited beneath NRDWL are well suited to analysis using regression-based techniques that incorporate linear trend components in the east-west and north-south directions. For these reasons and because NRDWL is in an area that is not anticipated to be subjected to active groundwater remediation for the foreseeable future, TRIM was not extended into this area, and the universal kriging technique embedded in MEUK was used that includes the necessary linear trend components.

5.2 Groundwater Elevation Mapping

Groundwater elevation mapping was performed based on comprehensive groundwater elevation datasets obtained for calendar years 2013, 2014, 2015, and 2016, the four most recent comprehensive datasets available at the time the calculations were performed (the dataset for 2017 was incomplete at the time and could not be used to develop a reliable water-level map). Four years were evaluated because different datasets can produce differences in the interpretation of groundwater elevations and corresponding flow directions.

Groundwater elevation mapping was performed using the MEUK technique (Tonkin et al., 2016), which is an extension of the hybrid mapping technique that combines universal kriging and the analytic element method. MEUK, which is implemented in the water-level mapping program KT3D-H2O (Karanovic et al., 2009, "KT3D_H20: A Program for Kriging Water Level Data Using Hydrologic Drift Terms"), is designed to create a series of related maps, each corresponding to a specific event that can exhibit spatial relationships that persist over time. MEUK assumes that multi-event (multi-year) data can be described by a combination of (a) trends that vary over time, (b) trends that are invariant over time, and (c) a spatially and temporally stationary correlation among the residuals of those trends. Compared to traditional kriging, MEUK provides improved trend estimates when the spatial distribution of monitoring locations differs from event to event. Using MEUK, all occasions for which water levels are measured are interpolated simultaneously through the solution of a single block-diagonal multi-event matrix. Thus, water-level data from all events are evaluated simultaneously within a single operation, which enables trend coefficients and interpolated maps to be conditioned on the entire dataset. MEUK can produce maps that honor measured data exactly and, once reviewed for consistency with independent information, can be used to evaluate groundwater flow directions and rates. The maps also can be used in conducting approximate contaminant transport analyses that incorporate advective-dispersive particle tracking without recourse to (or in combination with) a groundwater model.

A more detailed summary of the MEUK analysis is provided in Section 3.1 in ECF-200PO1-18-0010. Chapters 3 through 7 of ECF-200PO1-18-0010 describe the conceptual basis for the general calculations performed for NRDWL, detail the specific methods and codes used, and present the results of the calculations.

5.3 Vertical Migration

Analysis presented in Section 7.3 of ECF-200PO1-18-0010 concludes that the American Petroleum Institute (API) calculator is appropriate for use for assessment of vertical migration in the area of NRDWL and that, based on present conditions, no significant vertical migration is expected in the NRDWL area. The results of the evaluation suggest that any vertical movement that might occur would be limited to areas near partially penetrating extraction wells. There are no groundwater extraction wells in the vicinity of NRDWL, and none are planned for the foreseeable future; thus, the monitoring wells are all closer to potential contaminant release locations within NRDWL than to any groundwater pumping wells. Given this condition, the API plume diving calculator provides reliable estimates of the likely average rate of vertical migration of dissolved constituents moving downgradient from their hypothetical location of release at the water table. The API calculator was used to verify the appropriateness of the depths of the well screens for monitoring wells. DNAPLs have been detected in soil gas at NRDWL. Limited DNAPL transport to the groundwater is possible but unlikely. The results of the API calculator for the monitoring wells at NRDWL are presented in Section 7.3.3.3 of ECF-200PO1-18-0010.

5.4 Particle Tracking

The groundwater elevation maps depict general patterns of hydraulic gradients and groundwater flow, identifying likely directions of contaminant migration in case a release from a facility reaches the water table. Particle tracking provides a way to visualize the directions and potential paths of contaminant migration, enabling a more detailed assessment of the efficacy of a monitoring well network. Particle tracking was performed using the particle-tracking code ModPath3DU.

For the regional-scale analysis, particle tracking was performed first considering only advective migration and then considering both advective and dispersive migration mechanisms.

Particle-tracking calculations assuming advective and dispersive migration were performed for an instantaneous release of a large number of particles from NRDWL. Parameters used to calculate particle tracks assume migration of a conservative (i.e., nonreactive) dissolved contaminant under representative conditions. The particle-tracking calculations produced outputs specific to NRDWL, including particle pathlines and particle counts. Chapters 3 through 7 of ECF-200PO1-18-0010 describe the conceptual basis for the general calculations performed for NRDWL, detail the specific methods and codes used, and present the results of the calculations.

5.4.1 Particle Pathlines

Calculated particle pathlines illustrate how a hypothetical release to the water table from the facility would move and spread under the flow conditions estimated for each of the four mapped years (2013, 2014, 2015, and 2016). The facility-specific particle-tracking calculations and outputs are based on the one-time, instantaneous release of a large number of particles to the water table. This approach produces many pathlines, each of which depicts the hypothetical path of a particle of dissolved contaminant that reaches the water table beneath the facility. Because vadose zone travel time is ignored, the year of the hypothetical particle release is also the year that contamination reaches the water table. The particle paths were post-processed to provide additional depictions and calculations, including particle counts at well locations and contour maps of particle density (particle count maps).

5.4.2 Particle Counts

Calculated particle counts can serve as a surrogate for contaminant concentration to evaluate the relative efficacy of the interim status groundwater monitoring wells and the need for and suitability of any proposed new monitoring wells. Particle counts and relative arrival times at well locations were calculated by counting the number of particles that pass through the vicinity of an existing or potential monitoring well location and recording the time of arrival. A radius of 20 m (66 ft) around each well location was used to count particles as they arrived. The calculations produce two outputs that can help evaluate the groundwater monitoring well network:

- A tabulation of particle density (counts) for each downgradient interim status groundwater monitoring well and each potential new monitoring well. This count is the total number of particles that pass through the vicinity of the well, regardless of time.
- For each well location, a time-series plot of the likely arrival, peak, and decline in the (relative) concentration of particles resulting from an instantaneous release from NRDWL. This plot is prepared by summing the particles within a small number of arrival time bins in the manner used to construct a histogram.

Particle counts were also used to create particle count maps that depict areas of relatively higher and lower potential impact from a release that reaches the water table from a given facility. Contour maps of particle counts were generated by counting the number of particles that pass through a pre-defined uniform calculational grid. The grid, which is specific to each facility, is oriented parallel to the predominant groundwater flow direction, as shown in Figure 5-2.

5.4.3 Output

The outputs of the particle-tracking calculations include the following:

- Maps of calculated particle paths for the flow conditions determined for each of the four years (2013, 2014, 2015, and 2016)
- Time-series plots, referred to as particle breakthrough curves, of the relative arrival, peak, and decline in particle counts at each interim status groundwater monitoring well location and any proposed monitoring well location
- Tabulation of relative particle counts for each interim status groundwater monitoring well location and any proposed monitoring well location
- Maps of particle counts downgradient of the facility based on the flow conditions determined for each of the four years

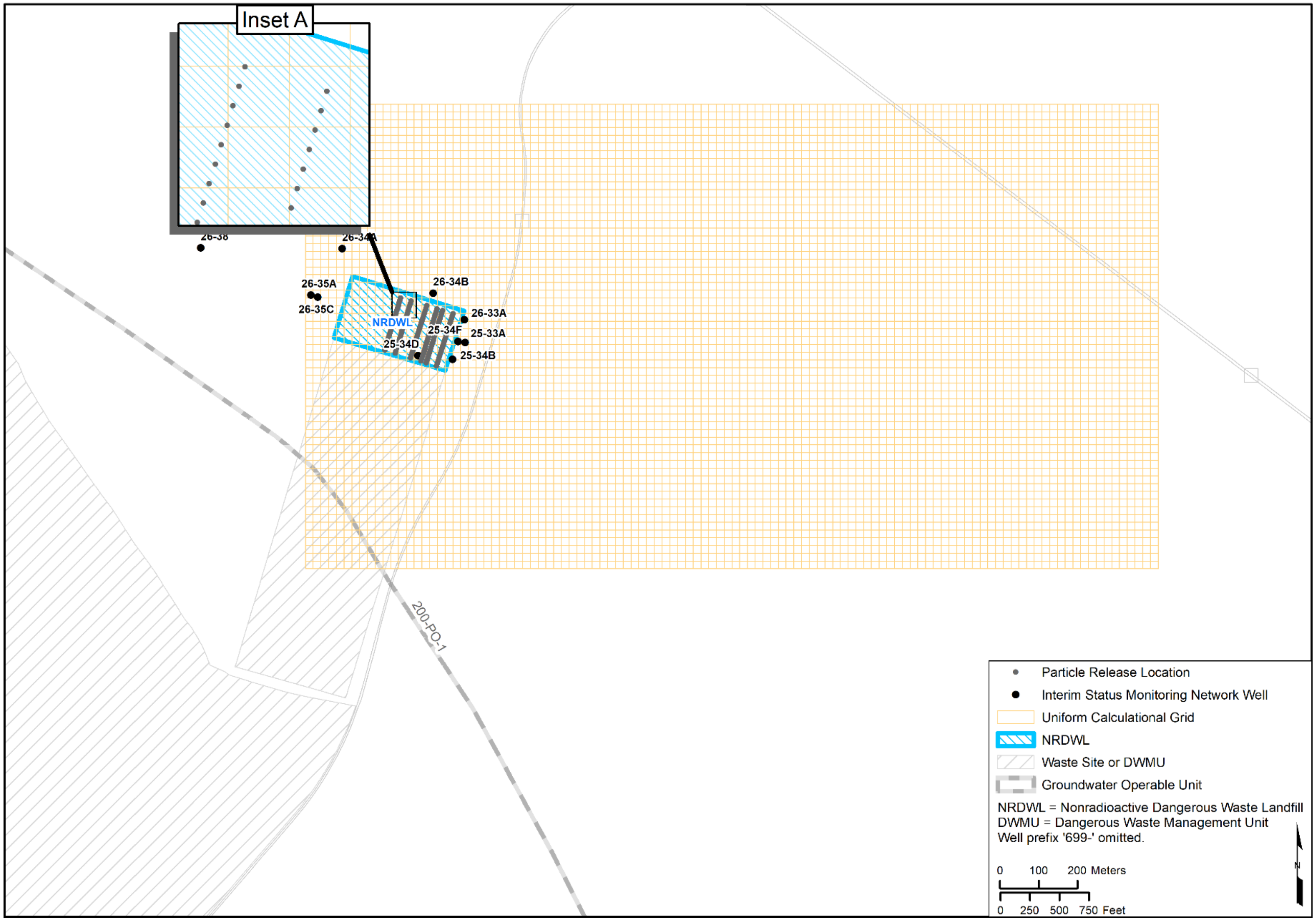


Figure 5-2. Particle Release Locations and Uniform Calculational Grid at NRDWL

6 Calculations

The assumptions, inputs, and calculation steps used to perform groundwater elevation mapping and particle tracking for NRDWL are discussed in this chapter. Additional details on the calculations are included in Chapter 4 of ECF-200PO1-18-0010.

6.1 Assumptions and Inputs for Groundwater Elevation Mapping

Water-level contour maps were constructed using a technique that incorporates the effects of certain hydrologic features such as groundwater pumping and large-scale transitions in aquifer properties (SGW-42305, *Collection and Mapping of Water Levels to Assist in the Evaluation of Groundwater Pump-and-Treat Remedy Performance*). While accounting for the values of water levels measured at each well, the contour maps also provide a plausible interpretation of groundwater levels and hydraulic gradients between measured locations. The accuracy of the contours is affected, however, by various factors, including the following:

- The degree of adherence to, or violation of, assumptions that underlie the mapping method (as outlined in SGW-42305)
- The accuracy of the measured or recorded water levels
- The number, distribution, and location of monitoring wells
- The relationships between the vertical open interval(s) of the monitoring wells and those of any extraction and injection wells
- The presence, continuity, and contrasts in hydraulic properties between large-scale aquifer zones

These potential sources of error mean that the interpolated maps only approximate actual conditions. The maps of water elevations and particle paths are considered reasonable approximations that provide value when interpreting the likely directions and rates of groundwater movement. The maps also help identify downgradient areas that likely would be impacted by a release that reached the underlying water table from NRDWL. Incorporating data for multiple groundwater elevation events (years) helps in developing a reasonable estimate of potential migration pathways.

To represent a direction of regional flow, line drift control points were created along the Columbia River, and river stage values from March 2016 were added to the kriging dataset. Those control points were set constant for all events. Additional drift terms are described in ECF-200PO1-18-0010.

6.2 Particle-Tracking Assumptions and Input

Particle-tracking calculations specific to NRDWL were performed for one-time releases to the water table that occur simultaneously from the six trenches that contained dangerous waste. The particle releases represent a hypothetical instantaneous release from NRDWL that reaches the water table. This release scenario does not incorporate any aspects of transport through the overlying vadose zone. After particles enter the groundwater, particle movement is predominantly horizontal, with minor components of vertical migration in response to limited infiltration from groundwater recharge. The monitoring wells were assumed to be screened across the water table so that samples collected from them would reflect the quality of water at or close to the water table. Because of this, particle counts were not evaluated for deep wells. Because particle tracking relies upon outputs (mapped groundwater elevations) computed using MEUK, the assumptions and limitations that underlie the preparation of those maps using MEUK are implicit in any subsequent particle tracking.

6.2.1 Particle Release Locations

The starting locations for particle-tracking calculations represent the area over which a potential release from a given facility likely would impact the underlying water table. Release locations were evenly spaced along each of the six trenches that contain dangerous waste (Figure 5-2). Twenty particles were released and tracked from each release location to provide the density of particles in space and time required for performing detailed facility-specific calculations, randomizing the seed values for the dispersion calculations. In total, 2,640 particles were released from the trenches and were tracked in the simulations performed for each of the four events (years).

6.2.2 Migration Parameters

Only a few parameters are required for performing migration calculations using groundwater elevation maps and particle-tracking methods. The parameters used to represent dissolved contaminant migration are representative of local conditions for a conservative (i.e., nonreactive) solute dissolved within groundwater.

Particle tracking that considers advection and dispersion relies upon the assumption that the values of the dispersion coefficients in the two principal directions (longitudinal and transverse) are representative of physical processes that act to disperse dissolved constituents in groundwater at the scale of the calculations. The values of the dispersivity parameters used in this evaluation were those used for this area within the CPGWM (CP-47631). Those values were as follows:

- Longitudinal dispersivity: 3.5 m (11.5 ft)
- Transverse dispersivity: 0.7 m (2.3 ft)

The local-scale parameters of mobile (effective) porosity and hydraulic conductivity are defined specific to NRDWL based on previous work detailed in ECF-Hanford-16-0013, *Hydraulic Gradients and Velocity Calculations for RCRA Sites in 2015*. They are as follows:

- Mobile porosity: 0.1
- Hydraulic conductivity: 1,500 m/d (4,921 ft/d)

The primary purpose of the calculations was to estimate directions of potential contaminant migration in order to assess the efficacy of the geographical distribution of wells in the monitoring network. For the calculations performed for NRDWL, the values assigned to the hydraulic conductivity and mobile (effective) porosity do not affect the assessment of well locations. The values assigned to those parameters do, however, affect the calculations of relative arrival times at existing and potential monitoring well locations.

6.3 Calculation Steps

The following steps were taken to produce the results presented in this evaluation.

6.3.1 Groundwater Elevation Maps

To prepare the water elevation maps presented in Figures 3-4 through 3-7, measured groundwater elevations were obtained for March 2013, 2014, 2015, and 2016. Water levels for which there were multiple measurements (such as the automated water-level network wells) were averaged so that one value was assigned to each monitoring well for each calendar year.

After setting the control points and drift terms, MEUK was executed to generate water-level contours for NRDWL. Using the water-level contours as the basis, the steps described below were implemented to perform the calculations and post-process the outputs to produce results specific to potential releases at NRDWL.

6.3.2 Particle Tracking

For the particle-tracking calculations, a file representing particle starting locations was prepared to use as input to the ModPath3DU program. Particles were released at the water table simultaneously from all particle starting locations to reflect a potential water table impact during each water-level mapping event (i.e., calendar year 2013, 2014, 2015, or 2016). Twenty particles were released and tracked from each particle starting location using a different random seed value for the dispersion calculations.

Then ModPath3DU was executed to produce a pathline output file. A post-processing program was executed to convert the pathline output file into both shapefile and text file format, both of which list particle locations and times.

6.3.3 Particle Counts

Particle counts were calculated to create maps that illustrate the relative particle density downgradient of NRDWL from a simulated release at the landfill and to produce time-series plots, or breakthrough curves. The breakthrough curves show the relative arrival times of particles at the various monitoring well locations.

To create particle count maps, a uniform calculational grid was defined having a 20 by 20 m (66 by 66 ft) cell size, large enough to envelop all pathlines generated during particle tracking (Figure 5-2). The grid is oriented parallel to the predominant direction of groundwater flow. Particles that pass through the calculational grid are counted, enabling production of a contour map of particle counts for each grid cell. Using the calculational grid and the shapefile output from the particle tracking for each of the four water-level mapping events, a count of unique pathlines intersecting each cell of the calculational grid was determined, creating a grid of pathline counts. Bilinear interpolation was used between cells of the pathline count grids to create particle count maps that depict the density of particles that passed through the mapped area.

The text file containing the particle locations and times that was generated based on particle tracking was used to calculate the particle counts and particle breakthrough curves for each interim status groundwater monitoring well. Using the text file, the pathlines were filtered to determine those that were first to pass within 20 m (66 ft) of each interim status monitoring well. The corresponding tracking time for each particle was recorded. The total number of pathlines that passed within 20 m (66 ft) of a specific well within a stipulated time period was summed. The results were tabulated and plotted as particle breakthrough curves.

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7 Simulation Results and Conclusions

This chapter presents the results and conclusions from evaluating the ability of the interim status groundwater monitoring network at NRDWL to detect hypothetical releases from the landfill. Water elevation mapping for calendar years 2013, 2014, 2015, and 2016 forms the basis for the facility-specific calculations. The water elevation maps presented as Figures 3-4 through 3-7 in Chapter 3 indicate a flow direction and hydraulic gradient consistently to the east and east-southeast for the four mapped years.

Based on the water-level maps, particle tracking was performed to simulate a hypothetical instantaneous release to the water table from all particle release locations within NRDWL. As described in Chapter 5, the outputs of particle-tracking calculations include the following:

- Maps of calculated particle pathlines for the flow conditions determined for each of the four simulated years
- Time-series plots, referred to as particle breakthrough curves, of the relative arrival, peak, and decline in particle counts at each interim status groundwater monitoring well location and any proposed monitoring well location
- Particle count tables for each interim status groundwater monitoring well location and any proposed monitoring well location
- Maps of particle counts downgradient of the facility given the flow conditions determined for each of the 4 years

The maps of particle pathlines are presented in Section 7.1; particle count maps and a summary of the particle count tables and breakthrough curves are provided in Section 7.2; and Section 7.3 presents the conclusions from this evaluation of the monitoring well network.

7.1 Particle Pathlines

Figures 7-1 through 7-4 depict the particle pathlines developed based on the mapped groundwater elevations and given a release of a large number of particles at NRDWL. The calculations of particle pathlines accounted for both advection and dispersion, therefore depicting the patterns that the migration of contaminants might display for the flow conditions determined for calendar years 2013, 2014, 2015, and 2016. Figures 7-1 through 7-4 depict the particle paths calculated after 1,000 days of travel, by which time it was determined that all particles would have arrived at or passed by the interim status groundwater monitoring wells.

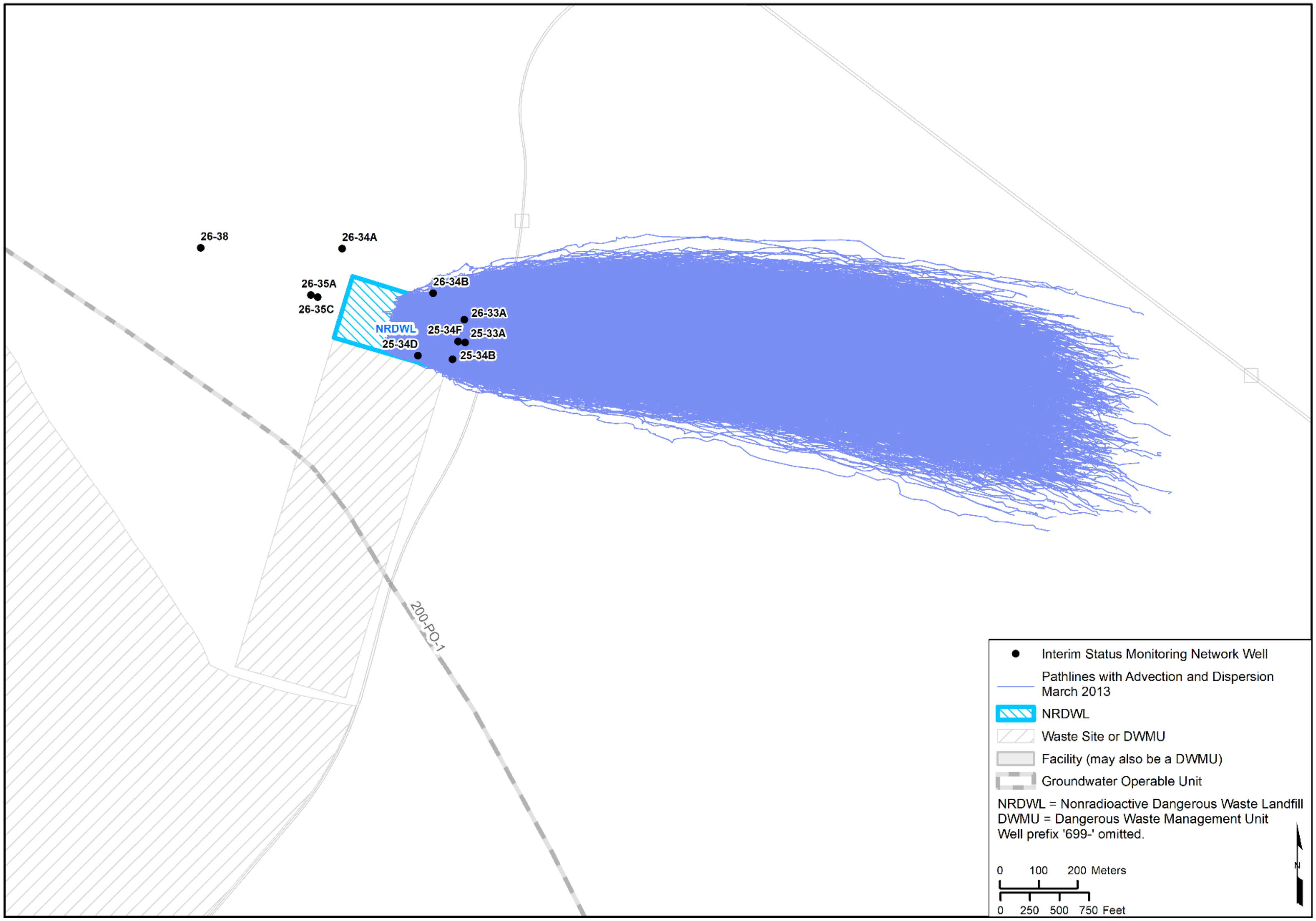

Figure 7-1. Local-Scale Particle Paths, Advection and Dispersion – NRDWL, 2013

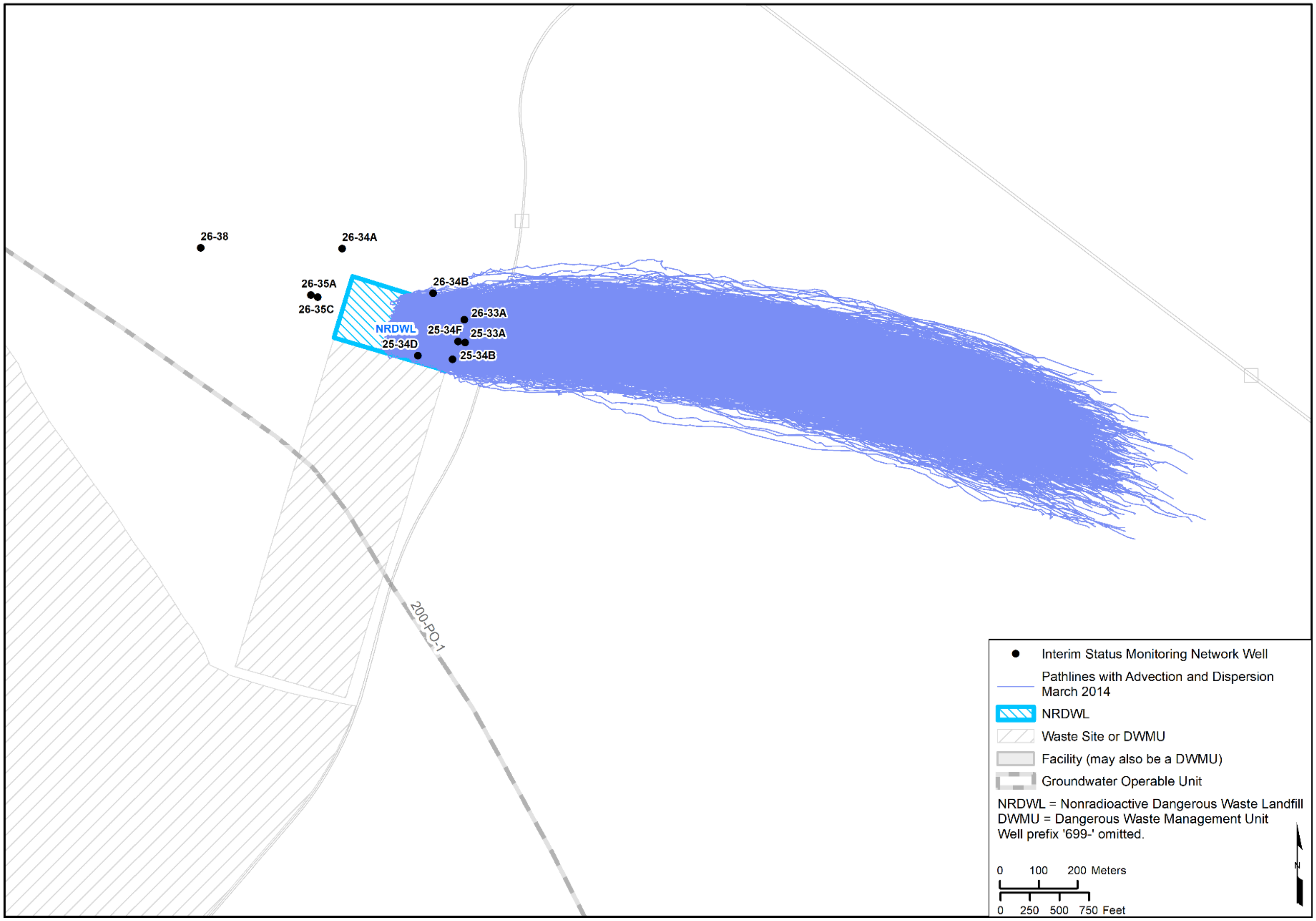

Figure 7-2. Local-Scale Particle Paths, Advection and Dispersion – NRDWL, 2014

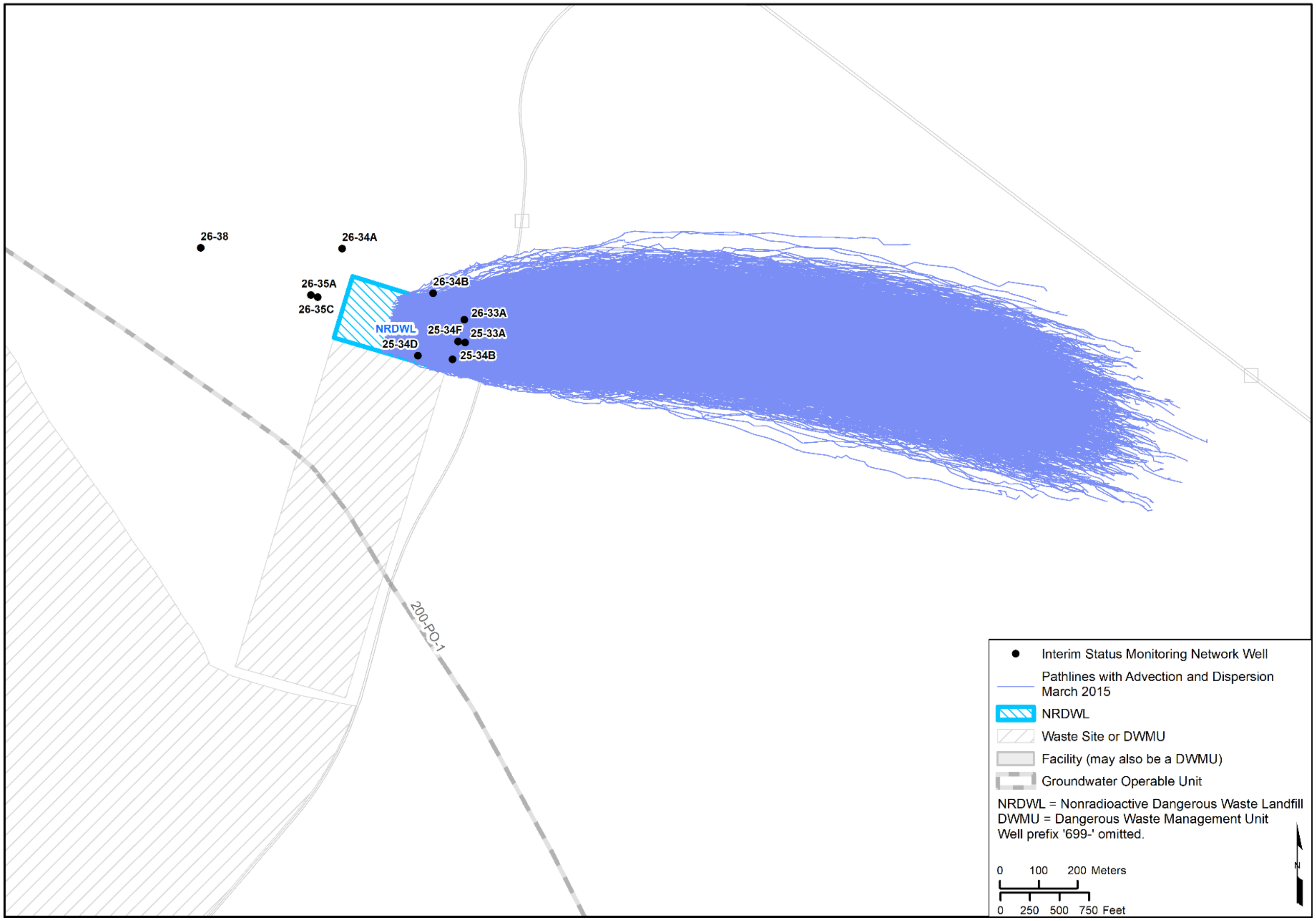

Figure 7-3. Local-Scale Particle Paths, Advection and Dispersion – NRDWL, 2015

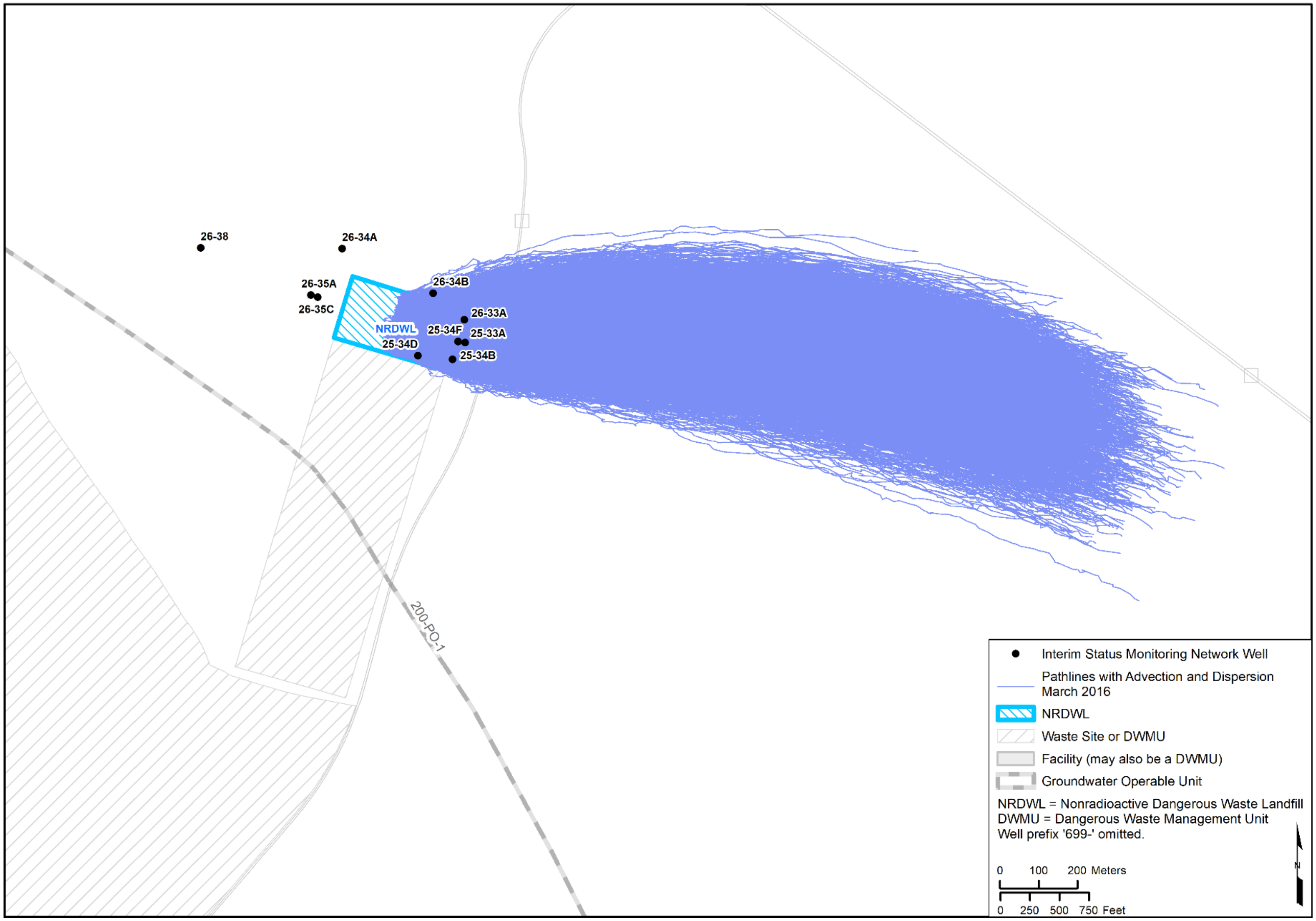

Figure 7-4. Local-Scale Particle Paths, Advection and Dispersion – NRDWL, 2016

7.2 Particle Counts

The particle breakthrough curves and particle count tables prepared for downgradient monitoring wells 699-26-33A, 699-25-34F, and 699-25-34B and crossgradient wells 699-25-34D and 699-26-34B are included in Chapter 7 in ECF-200PO1-18-0010. Because downgradient deep well 699-25-33A is not screened across the water table, particle counts were not evaluated at that well. The total number of particles that passed within the vicinity of each well can be compared to evaluate which well locations received a higher particle density and therefore are more likely to detect concentrations of contaminants released from the facility given the full range of particle release locations. The relative time of arrival of particles at each well also can be compared.

After the total number of particles that passed each well location was calculated for each year (2013, 2014, 2015, and 2016), an average value was calculated for all four years:

- 699-25-34D – Average = 307
- 699-26-34B – Average = 104.5
- 699-26-33A – Average = 677
- 699-25-34F – Average = 667
- 699-25-34B – Average = 512

The average particle counts can be used to assess the relative potential for each well to detect a release from the facility. In this case, wells 699-26-33A, 699-25-34F, and 699-25-34B are located in areas of high potential for detecting releases from NRDWL.

Particle count maps identify areas of the aquifer where a hypothetical release that impacts the water table beneath NRDWL would be most likely to migrate and be detectable. Figures 7-5 through 7-8 depict the particle count maps developed based on releasing a large number of particles simultaneously beneath the six trenches that contain dangerous waste (release locations shown in Figure 5-2). Plausible release locations were placed beneath the trenches that contain dangerous waste because the specific location where a release might occur cannot be predicted. Particle movement is analyzed considering both advection and dispersion for all the likely release locations, given the groundwater flow conditions estimated for calendar years 2013, 2014, 2015, and 2016. Figures 7-5 through 7-8 depict the particle density for the flow conditions estimated for the 4 years after 1,000 days of calculated travel, by which time it was determined that all particles would have arrived at or passed by the interim status groundwater monitoring wells (Tables 7-2 through 7-6 in ECF-200PO1-18-0010).

Figure 7-5. Particle Count Map – NRDWL, 2013

Figure 7-6. Particle Count Map – NRDWL, 2014

Figure 7-7. Particle Count Map – NRDWL, 2015

Figure 7-8. Particle Count Map - NRDWL, 2016

7.3 Simulation Conclusions

Based on the results of the calculations presented in ECF-200PO1-18-0010 and summarized herein, the proposed final status groundwater monitoring well network for detecting a potential release from NRDWL includes 10 monitoring wells from the interim status groundwater monitoring well network. Those wells are upgradient wells 699-26-38, 699-26-35A, and 699-26-34A; downgradient wells 699-26-33A, 699-25-34F, and 699-25-34B; deep wells 699-26-35C and 699-25-33A; and crossgradient wells 699-26-34B and 699-25-34D. No new wells are proposed to be added to the final status monitoring network.

The calculations based on the mapped water-level events indicate that the downgradient groundwater monitoring wells that were evaluated are well placed for detecting a release to the water table from NRDWL. Upgradient wells remain upgradient in all the events that were evaluated.

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8 Identification of Site-Specific Monitoring Constituents

An evaluation of the waste constituents associated with NRDWL was performed to identify the proposed groundwater monitoring constituents to include in the final status groundwater monitoring program. The evaluation process and proposed monitoring constituents are summarized in this chapter and detailed in ECF-200PO1-18-0031, *Identification of Site-Specific Monitoring Constituents for the Nonradioactive Dangerous Waste Landfill*.

8.1 Selection Process for Monitoring Constituents

The waste constituents associated with NRDWL are the dangerous wastes identified in the Hanford Facility RCRA Permit Part A Permit Application for NRDWL. These wastes were used to identify potential monitoring constituents. Potential monitoring constituents were evaluated to identify those constituents to be monitored under the final status permit.

The evaluations were performed in accordance with the summary descriptions provided in Sections 8.1 and 8.2. Additional details of the methodology are provided in Chapter 3 of ECF-200PO1-18-0031with assumptions documented in Chapter 4 of ECF-200PO1-18-0031.

8.1.1 Identification of Hanford Facility RCRA Permit Part A Dangerous Wastes and Mobility Evaluation

The Hanford Facility RCRA Permit Part A Application for NRDWL identifies the dangerous waste codes associated with the unit. A list of dangerous wastes and their corresponding Chemical Abstracts Service numbers was compiled using the waste codes (Table 2-1).

The specified dangerous wastes were screened to identify mobile constituents by comparing literature reference values for constituent distribution coefficient (K_d) to a Hanford Site-derived K_d value of 0.8 mL/g that was developed and applied to a known mobile constituent in Hanford Site vadose soils (hexavalent chromium) (Section 6.1 in ECF-Hanford-11-0165, *Evaluation of Hexavalent Chromium Leach Test Data Conducted on Vadose Zone Sediment Samples from the 100 Area*). Constituents with a $K_d \leq 0.8$ mL/g were identified as mobile constituents and further evaluated as potential monitoring constituents (Tables 1 and 3 in ECF-200PO1-18-0031). If no reference K_d value was available for a constituent, the constituent was conservatively retained for further evaluation as a potential monitoring constituent.

8.1.2 Identification of Potential Monitoring Constituents Already Prescribed for Monitoring at NRDWL

Ecology Letter 16-NWP-143 provided direction for preparation of documents to support the final status permit revision at NRDWL. The letter directed that monitoring for WAC 173-303-110(3)(c) and (7) constituents be performed for 1 year. WAC 173-303-110(3)(c) references Ecology Publication No. 97-407, and WAC 173-303-110(7) references Appendix 5 of Ecology Publication No. 97-407. Because the waste constituents identified in Appendix 5 of Ecology Publication No. 97-407 will be included for background monitoring at NRDWL under the final status permit, the potential monitoring constituents that are also listed in Appendix 5 of Ecology Publication No. 97-407 were identified as proposed monitoring constituents without evaluation or screening.

8.1.3 Availability of Analysis

The constituents retained as potential monitoring constituents through the processes described in Sections 8.1.1 and 8.1.2 underwent a final evaluation that identified those to be included as proposed monitoring constituents to detect and monitor a hypothetical waste release from NRDWL that may impact groundwater. In this evaluation, the potential monitoring constituents that are not routinely analyzed by commercial laboratories were removed from consideration.

Potential monitoring constituents that were not excluded due to unavailability of analysis at commercial laboratories were identified as proposed monitoring constituents. These proposed monitoring constituents, combined with the proposed monitoring constituents identified from evaluations in Sections 8.1.1 and 8.1.2, comprise the proposed monitoring constituents for NRDWL.

8.2 Results of Selection of Groundwater Monitoring Constituents

Based on the evaluation of the dangerous wastes identified from the NRDWL Part A Permit Application, 43 waste constituents are identified as proposed monitoring constituents to detect and monitor any groundwater impacts from hypothetical dangerous waste releases at NRDWL (Table 8-1). Details of the constituent screening and selection process outcomes are provided in Chapter 7 of ECF-200PO1-18-0031 of this document.

Table 8-1. Proposed Groundwater Monitoring Constituents for NRDWL

Waste Constituent	CAS Number
1-Butanol (n-Butyl alcohol)	71-36-3
1,1,1-Trichloroethane (TCA)	71-55-6
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1
1,1,2-Trichloroethane	79-00-5
1,2-Dichlorobenzene (o-Dichlorobenzene)	95-50-1
1,2-Dichloroethane	107-06-2
1,4-Dioxane	123-91-1
2-Butanone (Methyl ethyl ketone)	78-93-3
2-Nitropropane	79-46-9
2-Propanone (Acetone)	67-64-1
2-Propenamide (Acrylamide)	79-06-1
2,4-Dinitrophenol	51-28-5
4-Methyl-2-pentanone (Methyl isobutyl ketone)	108-10-1
Acetonitrile (Methyl cyanide)	75-05-8
Acrylonitrile	107-13-1
Aniline	62-53-3
Benzene	71-43-2
Carbon disulfide	75-15-0
Carbon tetrachloride	56-23-5
Chlorobenzene	108-90-7

Table 8-1. Proposed Groundwater Monitoring Constituents for NRDWL

Waste Constituent	CAS Number
Chloroform	67-66-3
Cresols	1319-77-3
Cyclohexane	110-82-7
Cyclohexanone	108-94-1
Ethyl acetate	141-78-6
Ethyl ether	60-29-7
Ethylbenzene	100-41-4
Formic acid	64-18-6
Hydrazine	302-01-2
Isobutanol (Isobutyl alcohol)	78-83-1
Kepone	143-50-0
Methanol	67-56-1
Methylene chloride	75-09-2
Nitrobenzene	98-95-3
p-(Dimethylamino)azobenzene	60-11-7
Phenol	108-95-2
Pyridine	110-86-1
Tetrachloroethene (PCE)	127-18-4
Tetrahydrofuran	109-99-9
Toluene	108-88-3
Trichloroethene (TCE)	79-01-6
Trichlorofluoromethane	75-69-4
Xylenes (total)	1330-20-7

CAS = Chemical Abstracts Service

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9 Groundwater Monitoring

This chapter includes a description of the proposed final status groundwater monitoring program and identifies the monitoring network, constituents to be sampled and analyzed, and the sample frequency. A detailed groundwater monitoring plan will include corresponding details (e.g., sampling protocols, quality assurance project plan) necessary to meet the requirements of WAC 173-303-806(4)(xx)(E) and (F)(I) and (II).

9.1 Final Status Groundwater Monitoring Program Determination

The appropriate groundwater monitoring program (i.e., detection monitoring, compliance monitoring, corrective action monitoring) is determined using the requirements in WAC 173-303-645(2)(a). If there is no statistically significant evidence of a release (contamination) at the point of compliance, the DWMU is monitored under WAC 173-303-645(9), "Detection Monitoring Program." If groundwater monitoring has shown statistically significant evidence of a release (contamination) at the point of compliance, the DWMU is monitored under WAC 173-303-645(10), "Compliance Monitoring Program." If the groundwater protection standard (which may be defined at the time of permit issuance, or when dangerous constituents from a regulated unit have been detected [WAC 173-303-645(3)]) is exceeded, a corrective action program is implemented and the DWMU is monitored under WAC 173-303-645(11), "Corrective Action Program."

To date, a release to the environment (statistically significant evidence of contamination at the point of compliance) has not been observed at NRDWL. Therefore, NRDWL will be in detection monitoring under WAC 173-303-645(9) when NRDWL becomes a final status closure unit group in Revision 9 of the Hanford Facility Dangerous Waste Permit.

9.2 Point of Compliance Monitoring

The point of compliance is defined in WAC 173-303-645(6)(a) as "…a vertical surface located at the hydraulically downgradient limit of the waste management area that extends down into the uppermost aquifer underlying the regulated units." WAC 173-303-645(6)(b) further states, "The waste management area is the limit projected in the horizontal plane of the area on which waste will be placed during the active life of a regulated unit. The waste management area includes horizontal space taken up by any liner, dike, or other barrier designed to contain waste in a regulated unit. If the facility contains more than one regulated unit, the waste management area is described by an imaginary line circumscribing the several regulated units."

The results of the water table mapping described in Chapter 7 indicate that the locations of the three downgradient wells (699-25-34B, 699-25-34F, and 699-26-33A) and two downgradient/crossgradient wells (699-25-34D and 699-26-34B) proposed for the monitoring well network span the range of particle distribution as released from NRDWL. The well placement is suitable for detecting releases to the water table from NRDWL under the evaluated range of conditions. The proposed well locations comply with the intent of WAC 173-303-645(6), which is to delineate the vertical and horizontal limits of the waste management area in order to detect releases of waste constituents from the facility that would pose a potential risk to ground and surface water. The downgradient wells are proposed as the point of compliance wells. Additional details regarding selection of these wells are presented in Chapter 7. In order to monitor the vertical contamination distribution at the point of compliance, data from available deep wells will be evaluated from other groundwater monitoring programs in the immediate area of the DWMU. These additional wells will be defined in the groundwater monitoring plan and added to the monitoring well network for the DWMU.

9.3 Proposed Groundwater Monitoring Network

The proposed groundwater monitoring network for NRDWL consists of three background (upgradient) wells, five point of compliance (three downgradient and two downgradient/crossgradient wells) and two deep wells (information only) to monitor for potential releases to the water table from NRDWL (Figure 9-1). The monitoring well locations were evaluated based on water elevation mapping and particle-tracking simulations representing flow conditions for 4 years (2013 through 2016). Results of the simulations are presented in Chapter 7.

Well attributes are summarized in Table 9-1 and Appendix D. Each of the proposed network wells have been, or will be, constructed according to WAC 173-160, “Minimum Standards for Construction and Maintenance of Wells.” With the exception of deep wells, each well is, or will be, screened in the upper unconfined aquifer in order to yield sufficient groundwater for representative sampling. Sections 9.3.1 through 9.3.10 provide details supporting the selection of each of the proposed locations. Based on the API calculator (discussed in Section 7.3 in ECF-200PO1-18-0010), the depths of the monitoring wells screened across the top of the water table are appropriate.

Where possible, the groundwater monitoring network is intended to meet the requirements of WAC 173-303-645(8)(a). A description of groundwater flow direction pertaining to NRDWL is presented in Section 3.3. WAC 173-303-645(8)(a)(i) states that wells must be appropriately sited to, “Represent the quality of background groundwater that has not been affected by leakage from a regulated unit.” To meet the intent of WAC 173-303-645(8)(a)(i), background (upgradient) wells have been selected that would be representative of ambient conditions. They do not however, represent groundwater not affected by Hanford Site operations. Characterization of the contaminated groundwater, including concentrations of dangerous constituents and parameters, will be performed after sufficient samples have been collected in the first 2 years of monitoring to conduct statistical analyses.

WAC 173-303-645(8)(g), states, “In detection monitoring…data on each dangerous constituent specified in the permit will be collected from background wells and at the compliance point(s). The number and kinds of samples collected to establish background must be appropriate for the form of statistical test employed, following generally accepted statistical principles. The sample size must be as large as necessary to ensure with reasonable confidence that a contaminant release to groundwater from a facility will be detected…” However, WAC 173-303-645(8)(h)(v) allows that, “Another statistical test method may be submitted by the owner or operator and approved by the department.” The process for selection of a statistical method is found in Appendix G. Selection of the statistical method for use in NRDWL is discussed in Section 9.5.

Based on current groundwater flow direction to the east-southeast (Section 2.15 in DOE/RL-2016-66), the selected point of compliance wells will provide representative samples of the quality of groundwater passing the point of compliance (WAC 173-303-645(8)(a)(ii)). These locations allow for the detection of contamination when dangerous waste or dangerous constituents have migrated from the waste management area to the uppermost aquifer (WAC 173-303-645(8)(a)(iii)). Assessment of the vertical component of contaminant migration shows that wells screened in the top of the uppermost unconfined aquifer are suitable for monitoring based on the API calculator (discussed in ECF-200PO1-18-0010).

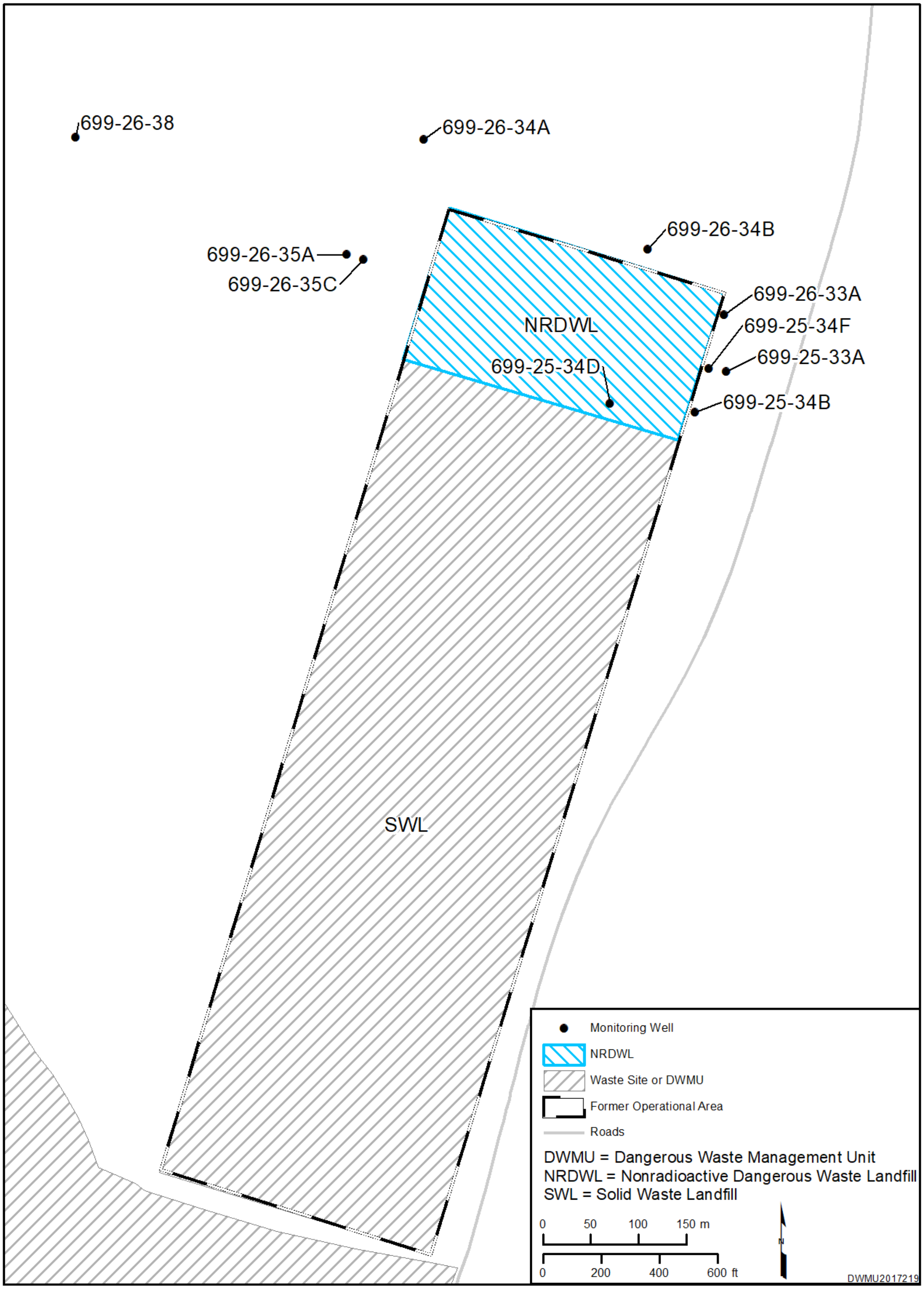

Figure 9-1. Proposed Final Status Groundwater Monitoring Network for NRDWL

Table 9-1. Attributes for Wells in the NRDWL Groundwater Monitoring Network

Well Name	Completion Date	Easting[a] (m)	Northing[a] (m)	Top of Casing Elevation (m [ft]) (NAVD88)	Water Table Elevation (m [ft]) (amsl)	Water Depth (m [ft] bgs)	Depth of Water in Screen (m [ft])	Water-Level Date
699-25-33A[b]	1/3/1987	579712.20	131224.57	162.2 (532.3)	121.5 (398.7)	40.1 (131.4)	3.0 (10.0)	1/8/2018
699-25-34B	9/5/1986	579679.42	131181.36	162.4 (532.7)	121.5 (398.7)	40.2 (131.9)	1.9 (6.3)	3/14/2018
699-25-34D	10/22/1992	579589.79	131190.90	165.0 (541.2)	121.5 (398.7)	42.4 (139.1)	7.0 (22.9)	3/14/2018
699-25-34F	9/8/2015	579693.92	131227.61	162.6 (533.3)	121.5 (398.7)	40.1 (131.7)	8.1 (26.5)	3/14/2018
699-26-33A	9/8/2015	579709.97	131284.02	164.5 (539.5)	121.5 (398.7)	41.9 (137.6)	8.0 (26.1)	3/14/2018
699-26-34A	7/3/1986	579394.84	131467.55	162.1 (531.7)	121.5 (398.7)	39.9 (131.0)	1.9 (6.3)	3/14/2018
699-26-34B	10/22/1992	579629.35	131352.25	162.6 (533.6)	121.5 (398.7)	39.9 (131.0)	6.9 (22.5)	3/14/2018
699-26-35A	7/14/1986	579314.11	131347.25	163.4 (536.0)	121.5 (398.7)	41.1 (134.9)	1.97 (5.5)	3/14/2018
699-26-35C[b]	1/5/1987	579332.03	131341.83	163.4 (536.0)	121.5 (398.7)	41.2 (135.2)	3.0 (10.0)	1/8/2018
699-26-38	2/26/2014	579030.19	131469.63	165.3 (542.3)	121.5 (398.8)	43.0 (141.2)	7.6 (24.9)	3/14/2018

Reference: NAVD88, *North American Vertical Datum of 1988*.

a. Coordinates are in Washington State Plane (south zone), NAD83, *North American Datum of 1983*; 1991 adjustment.

b. Deep well used for information only.

amsl = above mean sea level

bgs = below ground surface

9.3.1 Groundwater Monitoring Well 699-26-34A

Groundwater monitoring well 699-26-34A is proposed as a background well. It was constructed in 1986 to the standards of WAC 173-160. This well is used in the interim status groundwater monitoring network for NRDWL. The well is upgradient of NRDWL and is screened from elevation 125.7 m (412.4 ft) to elevation 119.6 m (392.4 ft) (Appendix D). Based on 2018 water elevation data, well 699-26-34A is screened across the upper 1.9 m (6.3 ft) of the uppermost unconfined aquifer (Table 9-1) and yields sufficient groundwater for representative sampling.

Water table mapping from 2016 indicates that the direction of groundwater flow is predominantly to the east at this well (Figures 3-7 and 7-4). Particle-tracking simulations were performed to evaluate the movement of constituents should there be a release (ECF-200PO1-18-0010 and Chapter 7). Based on the results of the simulations, this well will remain upgradient of NRDWL under expected groundwater flow conditions.

9.3.2 Groundwater Monitoring Well 699-26-35A

Groundwater monitoring well 699-26-35A is proposed as a background well. It was constructed in 1986 to the standards of WAC 173-160. This well is used in the interim status groundwater monitoring network for NRDWL. The well is upgradient of NRDWL and is screened from elevation 126.0 m (413.3 ft) to elevation 119.9 m (393.3 ft) (Appendix D). Based on 2018 water elevation data, well 699-26-35A is screened across the upper 1.97 m (5.5 ft) of the uppermost unconfined aquifer (Table 9-1) and yields sufficient groundwater for representative sampling.

Water table mapping from 2016 indicates that the direction of groundwater flow is predominantly to the east-southeast at this well (Figures 3-7 and 7-4). Particle-tracking simulations were performed to evaluate the movement of constituents should there be a release (ECF-200PO1-18-0010 and Chapter 7). Based on the results of the simulations, this well will remain upgradient of NRDWL under expected groundwater flow conditions.

9.3.3 Groundwater Monitoring Well 699-26-35C

Groundwater monitoring well 699-26-35C is proposed as a background deep well, to be used for information only. It was constructed in 1987 to the standards of WAC 173-160. This well is used for information only in the interim status groundwater monitoring network for NRDWL. The well is upgradient of NRDWL and is screened from elevation 103.9 m (341.0 ft) to elevation 100.9 m (331.0 ft) (Appendix D). Well 699-26-35C is a deep well and yields sufficient groundwater for representative sampling.

Water table mapping from 2016 indicates that the direction of groundwater flow is predominantly to the east-southeast at this well (Figures 3-7 and 7-4). Particle-tracking simulations were performed to evaluate the movement of constituents should there be a release (ECF-200PO1-18-0010 and Chapter 7). Based on the results of the simulations, this well will remain upgradient of NRDWL under expected groundwater flow conditions.

9.3.4 Groundwater Monitoring Well 699-26-38

Groundwater monitoring well 699-26-38 is proposed as a background well. It was constructed in 2014 to the standards of WAC 173-160. This well is used in the interim status groundwater monitoring network for NRDWL. The well is upgradient of NRDWL and is screened from elevation 123.1 m (403.9 ft) to elevation 114.0 m (373.8 ft) (Appendix D). Based on 2018 water elevation data, well 699-26-38 is screened across the upper 7.6 m (24.9 ft) of the uppermost unconfined aquifer (Table 9-1) and yields sufficient groundwater for representative sampling.

Water table mapping from 2016 indicates the direction of groundwater flow is predominantly to the east at this well (Figures 3-7 and 7-4). Particle-tracking simulations were performed to evaluate the movement of constituents should there be a release (ECF-200PO1-18-0010 and Chapter 7). Based on the results of the simulations, this well will remain upgradient of NRDWL under expected groundwater flow conditions.

9.3.5 Groundwater Monitoring Well 699-25-33A

Groundwater monitoring well 699-25-33A is proposed as a point of compliance well, to be used for information only. It was constructed in 1987 to the standards of WAC 173-160. This well is used for information only in the interim status groundwater monitoring network for NRDWL. The well is downgradient of NRDWL and is screened from elevation 103.4 m (339.1 ft) to elevation 100.3 m (329.1 ft) (Appendix D). Well 699-25-33A is a deep well and yields sufficient groundwater for representative sampling.

Water table mapping from 2016 indicates that the direction of groundwater flow is predominantly to the east at this well (Figures 3-7 and 7-4). Particle-tracking simulations were performed to evaluate the movement of constituents should there be a release (ECF-200PO1-18-0010 and Chapter 7). Based on the results of the simulations, this well will remain downgradient of NRDWL under expected groundwater flow conditions.

9.3.6 Groundwater Monitoring Well 699-25-34B

Groundwater monitoring well 699-25-34B is proposed as a point of compliance well. It was constructed in 1986 to the standards of WAC 173-160. This well is used in the interim status groundwater monitoring network for NRDWL. The well is downgradient of NRDWL and is screened from elevation 125.7 m (412.4 ft) to elevation 119.6 m (392.4 ft) (Appendix D). Based on 2018 water elevation data, well 699-25-34B is screened across the upper 1.9 m (6.3 ft) of the uppermost unconfined aquifer (Table 9-1) and yields sufficient groundwater for representative sampling.

Water table mapping from 2016 indicates that the direction of groundwater flow is predominantly to the east-southeast at this well (Figures 3-7 and 7-4). Particle-tracking simulations were performed to evaluate the movement of constituents should there be a release (ECF-200PO1-18-0010 and Chapter 7). Using this information, monitoring locations were evaluated against the ability to detect a release. Particle count maps were used to identify areas of the aquifer where a hypothetical release that impacts the water table beneath NRDWL would be most likely to migrate and be detectable. Figures 7-5 through 7-8 indicate that for all years mapped, well 699-25-34B is located within the likely migration area, in an area of high relative particle density.

9.3.7 Groundwater Monitoring Well 699-25-34D

Groundwater monitoring well 699-25-34D is a point of compliance well. It was constructed in 1992 to the standards of WAC 173-160. This well is used in the interim status groundwater monitoring network for NRDWL. The well is downgradient/crossgradient from NRDWL and is screened from elevation 125.3 m (411.0 ft) to elevation 114.5 m (375.8 ft) (Appendix D). Based on 2018 water elevation data, well 699-25-34D is screened across the upper 7.0 m (22.9 ft) of the uppermost unconfined aquifer (Table 9-1) and yields sufficient groundwater for representative sampling.

Water table mapping from 2016 indicates that the direction of groundwater flow is predominantly to the east-southeast at this well (Figures 3-7 and 7-4). Particle-tracking simulations were performed to evaluate the movement of constituents should there be a release (ECF-200PO1-18-0010 and Chapter 7). Particle count maps were used to identify areas of the aquifer where a hypothetical release that impacts the water table beneath NRDWL would be most likely to migrate and be detectable. Figures 7-5 through 7-8 indicate that for all years mapped, well 699-25-34D is located within the southern edge of the likely migration area, in an area of low relative particle density.

9.3.8 Groundwater Monitoring Well 699-25-34F

Groundwater monitoring well 699-25-34F is a point of compliance well. It was constructed in 2015 to the standards of WAC 173-160. This well is used in the interim status groundwater monitoring network for NRDWL. The well is downgradient of NRDWL and is screened from elevation 122.6 m (402.2 ft) to elevation 113.5 m (372.2 ft) (Appendix D). Based on 2018 water elevation data, well 699-25-34F is screened across the upper 8.1 m (26.5 ft) of the uppermost unconfined aquifer (Table 9-1) and yields sufficient groundwater for representative sampling.

Water table mapping from 2016 indicates that the direction of groundwater flow is predominantly to the east at this well (Figures 3-7 and 7-4). Particle-tracking simulations were performed to evaluate the movement of constituents should there be a release (ECF-200PO1-18-0010 and Chapter 7). Using this information, monitoring locations were evaluated against the ability to detect a release. Particle count maps were used to identify areas of the aquifer where a hypothetical release that impacts the water table beneath NRDWL would be most likely to migrate and be detectable. Figures 7-5 through 7-8 indicate that for all years mapped, well 699-25-34F is located within the likely migration area, in an area of high relative particle density.

9.3.9 Groundwater Monitoring Well 699-26-33A

Groundwater monitoring well 699-26-33A is a point of compliance well. It was constructed in 2015 to the standards of WAC 173-160. This well is used in the interim status groundwater monitoring network for NRDWL. The well is downgradient of NRDWL and is screened from elevation 122.7 m (402.6 ft) to elevation 113.6 m (372.6 ft) (Appendix D). Based on 2018 water elevation data, well 699-26-33A is screened across the upper 8.0 m (26.1 ft) of the uppermost unconfined aquifer (Table 9-1) and yields sufficient groundwater for representative sampling.

Water table mapping from 2016 indicates that the direction of groundwater flow is predominantly to the east at this well (Figures 3-7 and 7-4). Particle-tracking simulations were performed to evaluate the movement of constituents should there be a release (ECF-200PO1-18-0010 and Chapter 7). Using this information, monitoring locations were evaluated against the ability to detect a release. Particle count maps were used to identify areas of the aquifer where a hypothetical release that impacts the water table beneath NRDWL would be most likely to migrate and be detectable. Figures 7-5 through 7-8 indicate that for all years mapped, well 699-26-33A is located within the likely migration area, in an area of high relative particle density.

9.3.10 Groundwater Monitoring Well 699-26-34B

Groundwater monitoring well 699-26-34B is a point of compliance well. It was constructed in 1992 to the standards of WAC 173-160. This well is used in the interim status groundwater monitoring network for NRDWL. The well is downgradient/crossgradient from NRDWL and is screened from elevation 125.4 m (411.4 ft) to elevation 114.7 m (376.2 ft) (Appendix D). Based on 2018 water elevation data, well 699-26-34B is screened across the upper 6.9 m (22.5 ft) of the uppermost unconfined aquifer (Table 9-1) and yields sufficient groundwater for representative sampling.

Water table mapping from 2016 that indicates the direction of groundwater flow is predominantly to the east at this well (Figures 3-7 and 7-4). Particle-tracking simulations were performed to evaluate the movement of constituents should there be a release (ECF-200PO1-18-0010 and Chapter 7). Particle count maps were used to identify areas of the aquifer where a hypothetical release that impacts the water table beneath NRDWL would be most likely to migrate and be detectable. Figures 7-5 through 7-8 indicate that for all years mapped, well 699-26-34B is located within the northern edge of the likely migration area, in an area of low relative particle density.

9.4 Constituent List and Frequency

The proposed NRDWL final status groundwater monitoring network detailed in this report consists of three upgradient wells (699-26-34A, 699-26-35A, and 699-26-38), three downgradient wells (699-25-34B, 699-25-34F, and 699-26-33A), two crossgradient wells (699-25-34D and 699-26-34B), and two deep wells monitored for information only (699-26-35C [upgradient] and 699-25-33A [downgradient]). Each of these wells is part of the NRDWL interim status groundwater monitoring network (Table 3-2 in DOE/RL-2017-19) and are shown in Figure 9-1.

For a detection monitoring program, WAC 173-303-645(9)(a) requires, "The owner or operator must monitor for indicator parameters (e.g., pH, specific conductance, total organic carbon (TOC), total organic halogen (TOX), or heavy metals), waste constituents, or reaction products that provide a reliable indication of the presence of dangerous constituents in groundwater. The department will specify the parameters or constituents to be monitored in the facility permit…" Based on the analysis in Chapter 8, 43 waste constituents were selected to detect groundwater impacts from potential dangerous waste releases at NRDWL.

Table 9-2 identifies the proposed monitoring network and sampling frequency for NRDWL. The proposed site-specific monitoring constituents (Table 9-3) were identified in Chapter 8 (Table 8-1, with the addition of cadmium (added at the discretion of Ecology). The site-specific monitoring constituents will be sampled quarterly for the first 2 years of monitoring. After background concentrations are determined, the proposed monitoring constituents will be sampled semi-annually. Field measurements (pH, specific conductance, temperature, and turbidity) will be collected each time a well is sampled. Water-level measurements at each monitoring well will be determined each time a sample is obtained (WAC 173-303-645(8)(f)). Analytical performance, data evaluation, reporting, sampling protocols, and quality assurance requirements will be specified in the final status groundwater monitoring plan to be prepared for NRDWL.

In accordance with 16-NWP-143, performing 1 year of background monitoring for WAC 173-303-110(3)(c) and (7) constituents was established. WAC 173-303-110(3)(c) references Ecology Publication No. 97-407, and WAC 173-303-110(7) references Appendix 5 of Ecology Publication No. 97-407. Accordingly, the constituents identified in Appendix 5 of Ecology Publication No. 97-407 (Table 9-4) will be sampled for background monitoring. However, to support collection of sufficient samples to perform statistical testing (e.g., eight samples) and establish background concentrations, sampling for Ecology Publication No. 97-407 Appendix 5 constituents will be extended to a 2-year period and performed on a quarterly basis, after which sampling to establish background concentrations will be discontinued. Section 9.5 provides details on the number of sample data required to determine a statistical method.

Statistical evaluation of sampling results will be performed for site-specific monitoring constituents (Table 9-3) and the Appendix 5 dangerous wastes (Table 9-4), as appropriate. Information on the statistical method is provided in Section 9.5.

When the groundwater monitoring plan for NRDWL is incorporated into the Hanford Facility Dangerous Waste Permit, it will replace any other groundwater monitoring plan(s) associated specifically with this DWMU under interim status.

Table 9-2. Monitoring Wells and Sample Schedule for NRDWL

Well Name	Purpose	WAC Compliant	Water Level	Site-Specific Constituents to Detect Release from Regulated Unit[a]						Dangerous Wastes[b]	Field Parameters[e]
				Volatile Organic Compounds[c]	Semivolatile Organic Compounds[d]	Cadmium	Formic acid	Hydrazine	Methanol	Table 9-4	
699-26-34A	Upgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q	Q/S
699-26-35A	Upgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q	Q/S
699-26-35C[f]	Upgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q	Q/S
699-26-38	Upgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q	Q/S
699-25-33A[f]	Downgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q	Q/S
699-25-34B	Downgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q	Q/S
699-25-34F	Downgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q	Q/S
699-26-33A	Downgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q	Q/S
699-25-34D	Downgradient/ Crossgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q	Q/S

Table 9-2. Monitoring Wells and Sample Schedule for NRDWL

Well Name	Purpose	WAC Compliant	Water Level	Site-Specific Constituents to Detect Release from Regulated Unit[a]						Dangerous Wastes[b]	Field Parameters[e]
				Volatile Organic Compounds[c]	Semivolatile Organic Compounds[d]	Cadmium	Formic acid	Hydrazine	Methanol	Table 9-4	
699-26-34B	Downgradient/ Crossgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q	Q/S

Note: Complete reference citations are provided in Chapter 11.

a. Monitoring constituents will be sampled quarterly for the first 2 years of monitoring to determine background concentrations. After background concentrations are determined, these constituents will be monitored semiannually.

b. To establish background concentrations in accordance with 16-NWP-129, and to support collection of sufficient samples to perform statistical testing (e.g., eight samples), quarterly sampling for Ecology Publication No. 97-407 Appendix 5 constituents will be performed for a 2-year period.

c. Volatile organic compounds are provided in Table 9-3 and include 1-butanol (n-butyl alcohol); 1,1,1-trichloroethane (TCA); 1,1,2-trichloro-1,2,2-trifluoroethane; 1,1,2-trichloroethane; 1,2-dichloroethane; 2-butanone (methyl ethyl ketone); 2-nitropropane; 2-propanone (acetone); 4-methyl-2-pentanone (methyl isobutyl ketone); acetonitrile (methyl cyanide); acrylamide; acrylonitrile; benzene; carbon disulfide; carbon tetrachloride; chlorobenzene; chloroform, cyclohexane; cyclohexanone, ethyl acetate, ethyl ether, ethylbenzene, isobutanol (isobutyl alcohol); methylene chloride; tetrachloroethene (PCE); tetrahydrofuran; toluene, trichloroethylene (TCE), trichlorofluoromethane, and xylene (total).

d. Semivolatile organic compounds are provided in Table 9-3 and include 1,2-dichlorobenzene (o-dichlorobenzene); 1,4-dioxane; 2,4-dinitrophenol; aniline; cresols; kepone; nitrobenzene; p-(dimethylamino)azobenzene; phenol; and pyridine.

e. Field parameters include pH, specific conductance, temperature, and turbidity. Field parameters will be measured at each sample event (quarterly for the first 2 years of monitoring and semiannually thereafter).

f. Deep well, monitored for information only.

E = each time the well is sampled

Q = quarterly

S = semiannually

Y = well is, or will be, constructed as a resource protection well (WAC 173-160, "Minimum Standard for Construction and Maintenance of Wells")

WAC = *Washington Administrative Code*

Table 9-3. Proposed Groundwater Monitoring Constituents for NRDWL

Waste Constituent	CAS Number
Dangerous Waste Constituents	
1-Butanol (n-Butyl alcohol)	71-36-3
1,1,1-Trichloroethane (TCA)	71-55-6
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1
1,1,2-Trichloroethane	79-00-5
1,2-Dichlorobenzene (o-Dichlorobenzene)	95-50-1
1,2-Dichloroethane	107-06-2
1,4-Dioxane	123-91-1
2-Butanone (Methyl ethyl ketone)	78-93-3
2-Nitropropane	79-46-9
2-Propanone (Acetone)	67-64-1
2,4-Dinitrophenol	51-28-5
4-Methyl-2-pentanone (Methyl isobutyl ketone)	108-10-1
Acetonitrile (Methyl cyanide)	75-05-8
Acrylamide	79-06-1
Acrylonitrile	107-13-1
Aniline	62-53-3
Benzene	71-43-2
Cadmium	7440-41-7
Carbon disulfide	75-15-0
Carbon tetrachloride	56-23-5
Chlorobenzene	108-90-7
Chloroform	67-66-3
Cresols	1319-77-3
Cyclohexane	110-82-7
Cyclohexanone	108-94-1
Ethyl acetate	141-78-6
Ethyl ether	60-29-7
Ethylbenzene	100-41-4
Formic acid	64-18-6
Hydrazine	302-01-2
Isobutanol (Isobutyl alcohol)	78-83-1
Kepone	143-50-0

Table 9-3. Proposed Groundwater Monitoring Constituents for NRDWL

Waste Constituent	CAS Number
Methanol	67-56-1
Methylene chloride	75-09-2
Nitrobenzene	98-95-3
p-(Dimethylamino)azobenzene	60-11-7
Phenol	108-95-2
Pyridine	110-86-1
Tetrachloroethene (PCE)	127-18-4
Tetrahydrofuran	109-99-9
Toluene	108-88-3
Trichloroethene (TCE)	79-01-6
Trichlorofluoromethane	75-69-4
Xylenes (total)	1330-20-7

CAS = Chemical Abstracts Service

Table 9-4. Dangerous Waste Constituents for First 2 Years of Monitoring

Constituent	CAS Number	Constituent	CAS Number
Inorganic Constituents			
Antimony	7440-36-0	Mercury	7439-97-6
Arsenic	7440-38-2	Nickel	7440-02-0
Barium	7440-39-3	Selenium	7782-49-2
Beryllium	7440-41-7	Silver	7440-22-4
Cadmium	7440-43-9	Sulfide	18496-25-8
Chromium	7440-47-3	Thallium	7440-28-0
Cobalt	7440-48-4	Tin	7440-31-5
Copper	7440-50-8	Vanadium	7440-62-2
Cyanide	57-12-5	Zinc	7440-66-6
Lead	7439-92-1	--	--
Volatile Organic Compounds			
1,1-Dichloroethane	75-34-3	Carbon tetrachloride	56-23-5
1,1-Dichloroethene (1,1-Dichloroethylene)	75-35-4	Chlorobenzene	108-90-7
1,1,1-Trichloroethane	71-55-6	Chloroethane	75-00-3
1,1,1,2-Tetrachloroethane	630-20-6	Chloroform	67-66-3

Table 9-4. Dangerous Waste Constituents for First 2 Years of Monitoring

Constituent	CAS Number	Constituent	CAS Number
1,1,2-Trichloroethane	79-00-5	Chloroprene	126-99-8
1,1,2,2-Tetrachloroethane	79-34-5	Dibromochloromethane	124-48-1
1,2-Dibromo-3-chloropropane	96-12-8	p-Dichlorobenzene (1,4-Dichlorobenzene)	106-46-7
1,2-Dibromoethane	106-93-4	Dichlorodifluoromethane	75-71-8
1,2-Dichloroethane	107-06-2	Ethylbenzene	100-41-4
1,2-Dichloropropane	78-87-5	Ethyl methacrylate	97-63-2
trans-1,2-Dichloroethylene	156-60-5	Isobutanol (Isobutyl alcohol)	78-83-1
1,2,3-Trichloropropane	96-18-4	Methacrylonitrile	126-98-7
cis-1,3-Dichloropropene	10061-01-5	Methyl bromide (Bromomethane)	74-83-9
trans-1,3-Dichloropropene	10061-02-6	Methyl chloride (Chloromethane)	74-87-3
trans-1,4-Dichloro-2-butene	110-57-6	Methyl iodide (Iodomethane)	74-88-4
2-Butanone (Methyl ethyl ketone; MEK)	78-93-3	Methyl methacrylate	80-62-6
2-Propanone (acetone)	67-64-1	Methylene bromide (Dibromomethane)	74-95-3
2-Hexanone (Methyl butyl ketone)	591-78-6	Methylene chloride	75-09-2
4-Methyl-2-pentanone (Methyl isobutyl ketone)	108-10-1	Propionitrile (Ethyl cyanide)	107-12-0
Acetonitrile (Methyl cyanide)	75-05-8	Styrene	100-42-5
Acrolein	107-02-8	Tetrachloroethene (PCE)	127-18-4
Acrylonitrile	107-13-1	Toluene	108-88-3
Allyl chloride	107-05-1	Trichloroethene (TCE)	79-01-6
Benzene	71-43-2	Trichlorofluoromethane	75-69-4
Bromodichloromethane	75-27-4	Vinyl acetate	108-05-4
Bromoform	75-25-2	Vinyl chloride (Chloroethene)	75-01-4
Carbon disulfide	75-15-0	Xylenes (total)	1330-20-7
Semivolatile Organic Compounds			
1-Naphthylamine	134-32-7	Dimethyl phthalate	131-11-3
1,2-Dichlorobenzene (o-Dichlorobenzene)	95-50-1	Di-n-butyl phthalate	84-74-2
1,2,4-Trichlorobenzene	120-82-1	m-Dinitrobenzene	99-65-0
1,2,4,5-Tetrachlorobenzene	95-94-3	Di-n-octylphthalate	117-84-0
1,4-Dioxane	123-91-1	Dinoseb (2-sec-Butyl-4,6-dinitrophenol)	88-85-7

Table 9-4. Dangerous Waste Constituents for First 2 Years of Monitoring

Constituent	CAS Number	Constituent	CAS Number
1,4-Naphthoquinone	130-15-4	Diphenylamine	122-39-4
2-Acetylaminofluorene	53-96-3	Disulfoton	298-04-4
2-Chloronaphthalene	91-58-7	Ethyl methanesulfonate	62-50-0
2-Chlorophenol	95-57-8	Famphur	52-85-7
2-Methylphenol (o-cresol)	95-48-7	Fluoranthene	206-44-0
2-Methylnaphthalene	91-57-6	9H-Fluorene (Fluorene)	86-73-7
2-Naphthylamine	91-59-8	Hexachlorobenzene	118-74-1
2-Nitrophenol (o-Nitrophenol)	88-75-5	Hexachlorobutadiene	87-68-3
2-Picoline	109-06-8	Hexachlorocyclopentadiene	77-47-4
2,3,4,6-Tetrachlorophenol	58-90-2	Hexachloroethane	67-72-1
2,4-Dichlorophenol	120-83-2	Hexachlorophene	70-30-4
2,4-Dimethylphenol	105-67-9	Hexachloropropene	1888-71-7
2,4-Dinitrophenol	51-28-5	Indeno(1,2,3-cd)pyrene	193-39-5
2,4-Dinitrotoluene	121-14-2	Isodrin	465-73-6
2,4,5-Trichlorophenol	95-95-4	Isophorone	78-59-1
2,4,6-Trichlorophenol	88-06-2	Isosafrole	120-58-1
2,6-Dichlorophenol	87-65-0	Kepone	143-50-0
2,6-Dinitrotoluene	606-20-2	Methapyrilene	91-80-5
3-Methylcholanthrene	56-49-5	Methyl methanesulfonate	66-27-3
3-Methylphenol (m-Cresol)	108-39-4	Methyl parathion	298-00-0
4-Methylphenol (p-cresol)	106-44-5	Naphthalene	91-20-3
3,3′-Dichlorobenzidine	91-94-1	Nitrobenzene	98-95-3
3,3′-Dimethylbenzidine	119-93-7	o-Nitroaniline (2-Nitroaniline)	88-74-4
4-Aminobiphenyl	92-67-1	m-Nitroaniline (3-Nitroaniline)	99-09-2
4-Bromophenyl phenyl ether	101-55-3	p-Nitroaniline (4-Nitroaniline)	100-01-6
4-Chloro-3-methylphenol (p-Chloro-m-cresol)	59-50-7	p-Nitrophenol (4-Nitrophenol)	100-02-7
4-Chlorophenyl phenyl ether	7005-72-3	N-Nitrosodi-n-butylamine	924-16-3
4-Nitroquinoline 1-oxide	56-57-5	N-Nitrosodiethylamine	55-18-5
4,6-Dinitro-o-cresol (4,6-Dinitro-2-methyl phenol)	534-52-1	N-Nitrosodimethylamine	62-75-9
5-Nitro-o-toluidine	99-55-8	N-Nitrosodiphenylamine	86-30-6

Table 9-4. Dangerous Waste Constituents for First 2 Years of Monitoring

Constituent	CAS Number	Constituent	CAS Number
7,12-Dimethylbenz[a]anthracene	57-97-6	n-Nitroso-di-n-dipropylamine (N-Nitrosodipropylamine; Di-n-propylnitrosamine)	621-64-7
Acenaphthene	83-32-9	N-Nitrosomethylethalamine	10595-95-6
Acenaphthylene	208-96-8	n-Nitrosomorpholine	59-89-2
Acetophenone	98-86-2	N-Nitrosopiperidine	100-75-4
Aniline	62-53-3	N-Nitrosopyrrolidine	930-55-2
Anthracene	120-12-7	Parathion	56-38-2
Aramite	140-57-8	Pentachlorobenzene	608-93-5
Benz[a]anthracene (Benzo[a]anthracene)	56-55-3	Pentachloroethane	76-01-7
Benz[e]acephenanthrylene (Benzo[b]fluoranthene)	205-99-2	Pentachloronitrobenzene	82-68-8
Benzo[k]fluoranthene	207-08-9	Pentachlorophenol	87-86-5
Benzo[ghi]perylene	191-24-2	Phenacetin	62-44-2
Benzo[a]pyrene	50-32-8	Phenanthrene	85-01-8
Benzyl alcohol	100-51-6	Phenol	108-95-2
Bis(2-chloroethoxy)methane	111-91-1	p-Phenylenediamine	106-50-3
Bis(2-chloroethyl)ether	111-44-4	Phorate	298-02-2
Bis(2-chloro-1-methylethyl) ether (2,2'-Oxybis(1-chloropropane))	108-60-1	Pronamide	23950-58-5
Bis(2-ethylhexyl) phthalate	117-81-7	Pyrene	129-00-0
Butylbenzylphthalate	85-68-7	Pyridine	110-86-1
p-Chloroaniline (4-Chloroaniline)	106-47-8	Safrole	94-59-7
Chlorobenzilate	510-15-6	Tetraethyl dithiopyrophosphate	3689-24-5
Chrysene	218-01-9	o-Toluidine	95-53-4
Diallate	2303-16-4	O,O,O-Triethyl phosphorothioate	126-68-1
Dibenz[a,h]anthracene	53-70-3	sym-Trinitrobenzene	99-35-4
Dibenzofuran	132-64-9	Aroclor 1016	12674-11-2
m-Dichlorobenzene (1,3-Dichlorobenzene)	541-73-1	Aroclor 1221	11104-28-2
Diethyl phthalate	84-66-2	Aroclor 1232	11141-16-5
O,O-Diethyl O-2-pyrazinyl phosphorothioate	297-97-2	Aroclor 1242	53469-21-9
Dimethoate	60-51-5	Aroclor 1248	12672-29-6

Table 9-4. Dangerous Waste Constituents for First 2 Years of Monitoring

Constituent	CAS Number	Constituent	CAS Number
p-(Dimethylamino)azobenzene	60-11-7	Aroclor 1254	11097-69-1
alpha, alpha-Dimethylphenethylamine	122-09-8	Aroclor 1260	11096-82-5
Pesticides			
4,4′-DDD	72-54-8	Endosulfan I	959-98-8
4,4′-DDE	72-55-9	Endosulfan II	33213-65-9
4,4′-DDT	50-29-3	Endosulfan sulfate	1031-07-8
Aldrin	309-00-2	Endrin	72-20-8
alpha-BHC	319-84-6	Endrin aldehyde	7421-93-4
beta-BHC	319-85-7	Heptachlor	76-44-8
delta-BHC	319-86-8	Heptachlor epoxide	1024-57-3
gamma-BHC (Lindane)	58-89-9	Methoxychlor	72-43-5
Chlordane	57-74-9	Toxaphene	8001-35-2
Dieldrin	60-57-1	--	--
Herbicides			
2,4-D; 2,4-Dichlorophenoxyacetic acid	94-75-7	Silvex; 2,4,5-TP	93-72-1
2,4,5-T; 2,4,5-Trichlorophenoxyacetic acid	93-76-5	--	--
Polychlorinated Dibenzodioxins and Polychlorinated Dibenzofurans			
2,3,7,8-Tetrachlorodibenzo-p-dioxin	1746-01-6	Polychlorinated dibenzofurans	N/A
Polychlorinated dibenzo-p-dioxins	N/A	--	--

Note: This table identifies the dangerous waste constituents listed in Appendix 5 of Ecology Publication No. 97-407, *Chemical Test Methods For Designating Dangerous Waste WAC 173-303-090 & -100*.

CAS = Chemical Abstracts Service

N/A = not applicable

9.5 Statistical Method

At this time, a specific statistical method for the determination of statistically significant evidence of contamination from NRDWL cannot be determined. EPA 530/R-09-007, *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities Unified Guidance*, requires a minimum of eight samples to be able to define background. Since early 2017, NRDWL has been monitored under a groundwater quality assessment program. While the wells in the proposed network have been monitored during interim status, not all of the proposed monitoring constituents for final status have been included as monitoring constituents. Therefore, there are insufficient data to assess baseline conditions and determine a statistical method.

An accelerated sampling program is recommended to obtain sufficient samples to define baseline and determine a statistical method. This accelerated sampling program will monitor each of the constituents in Table 9-2 at a quarterly frequency for 2 years. Quarterly monitoring will allow for sufficiently long enough time between samples so as to not cause a problem with autocorrelation of samples (i.e., resampling the same water). After 2 years of sampling is completed, the statistical test method can be determined using the decision matrix included as Appendix E. In addition to this methodology, hydrogeology of the area also will be considered. Following this initial monitoring period and determination of the statistical method, the statistical method will be periodically reassessed.

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10 Routine Evaluation of the Monitoring Network

The groundwater flow regime will evolve over time. Throughout the year, water-level measurements are also taken as part of routine sampling, and annually for water-level mapping. Analysis of groundwater elevation, using universal kriging for water-level maps, and hydraulic gradient mapping will be used to interpret changes in the groundwater flow regime. Additionally, re-evaluation of the monitoring network will be performed annually in conjunction with the WAC 173-303-645(9)(e) determination of groundwater flow direction and rate in the uppermost aquifer. If the analysis suggests a change in the flow regime (e.g., changes resulting from a CERCLA remedy) that indicates that the likely migration direction of any hypothetical release is outside of or on the margins of the monitoring network for a DWMU, then particles will be released to re-evaluate the monitoring network for that DWMU.

Results of the re-evaluation of the monitoring network may result in a proposal to add additional monitoring well locations. In a given year, the results may show that there is no impact to a DWMU, in which case no action would be taken. If an impact to a DWMU is shown, the network would be re-evaluated and documented in an update to this engineering evaluation report, shared with Ecology, and placed in the operating record. An update to the engineering report would not necessarily result in an update to the associated groundwater monitoring plan if there is no resulting change needed to the groundwater monitoring network. If a change in the groundwater monitoring network is determined, a permit modification with a revised groundwater monitoring plan would be performed in accordance with WAC 173-303-815, “Facility-Specific Permit Conditions.”

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Appendix A

Interim Status Data Summary

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A1 Introduction

Section 2.4 of the main document summarizes the groundwater monitoring history at the Nonradioactive Dangerous Waste Landfill (NRDWL). An interim status indicator parameter groundwater monitoring program under 40 CFR 265, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," was initiated in 1986. The indicator parameter monitoring program continued until early 2009 when NRDWL was placed into a groundwater quality assessment monitoring program in accordance with 40 CFR 265.93(d), "Preparation, Evaluation, and Response." NRDWL was monitored under a groundwater quality assessment program until later in 2009, afterwhich it reverted back to an indicator evaluation program. NRDWL continued under an indicator evaluation program until 2017, when it again entered a groundwater quality assessment program. Groundwater monitoring at NRDWL has since continued a under groundwater quality assessment program during interim status.

The interim status groundwater monitoring history of NRDWL was compiled. Information from annual reporting documents and groundwater monitoring plans was used to compile a summary of wells in the NRDWL network, groundwater flow direction and rate, monitoring constituents, statistical comparison values (e.g., critical means), and a summary of comparison value exceedances or other contaminants (e.g., plumes from upgradient sources) in a Microsoft® Excel® workbook. Sampling data through December 31, 2016, for each well are presented in separate Microsoft Excel workbooks. Sample data for each well were retrieved from the Hanford Environmental Information System database. The workbooks are contained in electronic files to accompany this report.

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Appendix B

Topographic Map

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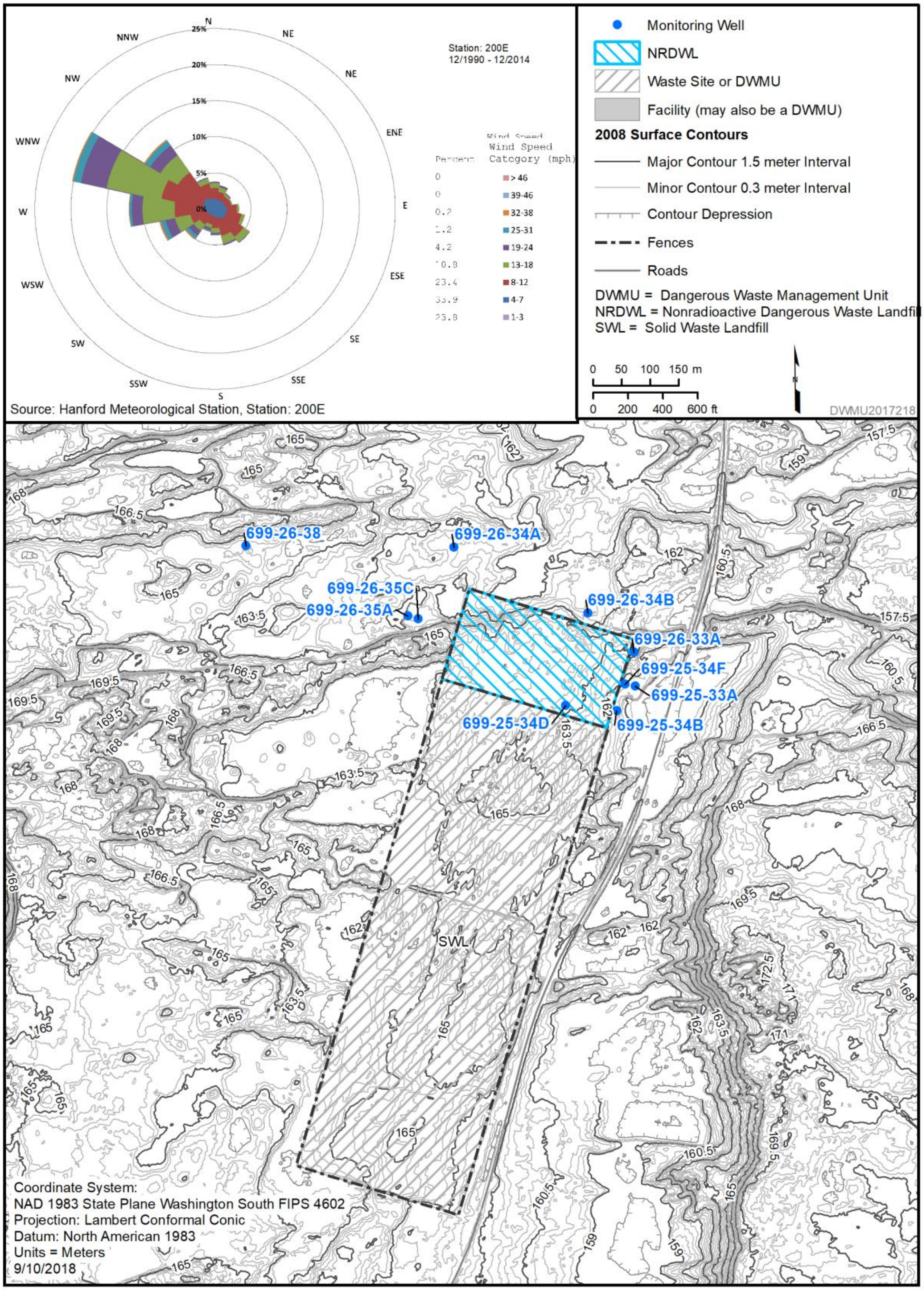

Figure B-1. Topographic Map

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Appendix C

Plume Maps

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C1 Plume Maps

This appendix presents regional plume maps in the vicinity of the subject dangerous waste management unit. There are no regional plumes in the vicinity of the Nonradioactive Dangerous Waste Landfill, nor are there plumes that are the result of hypothetical releases from the Nonradioactive Dangerous Waste Landfill.

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Appendix D

Well As-Built Diagrams

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Contents

Figures

Tables

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D1 Introduction

This appendix provides the following information for the existing Nonradioactive Dangerous Waste Landfill (NRDWL) groundwater monitoring wells:

- Well name
- Hydrogeologic unit monitored (the aquifer portion at the well screen perforation) (Table D-1)
- The following sampling interval information, as provided in Table D-2:
  - Elevation at the top of the screen or perforated interval
  - Elevation at the bottom of the screen or perforated interval
  - Open interval length (i.e., difference between the top and bottom screen perforation elevations)
  - Drilling method

Figures D-1 through D-10 provide construction and completion summaries for the existing network wells.

Table D-1. Hydrogeologic Monitoring Unit Classification Scheme

Unit	Description
LU	**Lower Unconfined.** Open interval begins at greater than 15.2 m (50 ft) below the water table and below the middle coarse hydrogeologic unit or within 15.2 m (50 ft) of the top of basalt and does not extend more than 3 m (10 ft) below the top of basalt.
TU	**Top of Unconfined.** Screened across the water table or the top of the open interval is within 1.5 m (5 ft) of the water table, and the bottom of the open interval is no more than 10.7 m (35 ft) below the water table.

Table D-2. Sampling Interval Information for Wells Within the NRDWL Network

Well Name	Hydrogeologic Unit Monitored	Elevation Top of Open Interval (m [ft] NAVD88)	Elevation Bottom of Open Interval (m [ft] NAVD88)	Open Interval Length (m [ft])	Drilling Method
699-25-33A	LU	103.4 (339.1)	100.3 (329.1)	3.1 (10.0)	Cable tool
699-25-34B	TU	125.7 (412.4)	119.6 (392.4)	6.1 (20.0)	Cable tool
699-25-34D	LU	125.3 (411.0)	114.5 (375.8)	10.7 (35.2)	Air rotary
699-25-34F	TU	122.6 (402.2)	113.5 (372.2)	9.2 (30.0)	Sonic
699-26-33A	TU	122.7 (402.6)	113.6 (372.6)	9.1 (30.0)	Sonic
699-26-34A	TU	125.7 (412.4)	119.6 (392.4)	6.1 (20.0)	Cable tool
699-26-34B	TU	125.4 (411.4)	114.7 (376.2)	10.7 (35.2)	Air rotary
699-26-35A	TU	126.0 (413.3)	119.9 (393.3)	6.1 (20.0)	Cable tool
699-26-35C	LU	103.9 (341.0)	100.9 (331.0)	3.1 (10.0)	Cable tool

Table D-2. Sampling Interval Information for Wells Within the NRDWL Network

Well Name	Hydrogeologic Unit Monitored	Elevation Top of Open Interval (m [ft] NAVD88)	Elevation Bottom of Open Interval (m [ft] NAVD88)	Open Interval Length (m [ft])	Drilling Method
699-26-38	TU	123.1 (403.9)	114.0 (373.8)	9.1 (30.0)	Cable tool

Reference: NAVD88, *North American Vertical Datum of 1988*.

LU = Lower Unconfined, as described in Table D-1

TU = Top of Unconfined, as described in Table D-1

WELL CONSTRUCTION AND COMPLETION SUMMARY AS-BUILT

Drilling Method: Cable Tool	Sample Method: Split spoon & Drill plug	WELL NUMBER: 699-25-33A TEMPORARY WELL NO.:
Drilling Fluid Used: Water	Additives Used:	Hanford Coordinates: N/S ____ E/W ____
Driller's Name: K. Olson	WA State Lic. No.: 1217	State Coordinates: N ____ E ____
Drilling Company: Onwego Drilling	Company Location: Kennewick	Start Card #: ____ T ____ R ____ S ____
Date Started: 12/1/86	Date Complete: 1/3/87	Elevation Ground Surface (ft): INF.

Depth to water: 112.0

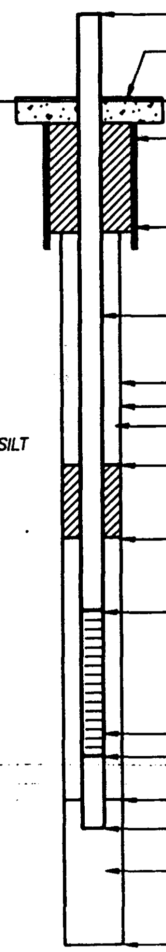
Data source: Driller's log

GENERALIZED STRATIGRAPHY

0–15: NO RECOVERY
15–30: SAND, SILT & GRAVEL
30–70: INF
70–78: SAND & GRAVEL
78–80: COBBLES
80–105: GRAVEL & COBBLES
105–108: GRAVEL & medium – fine SAND
108–125: SAND, GRAVEL & COBBLES
125–145: Fine SAND & GRAVEL
145–155: SAND, GRAVEL & COBBLES
155–161: SAND, SILT & fine GRAVEL
161–191: SILTY SAND
191–202: SILTY SAND with GRAVEL
202–223: INF
223–235: Cemented SAND & GRAVEL
235–239: Cemented SAND & GRAVEL with SILT
239–240: GRAVEL
240–245: SILTY SAND with TR CLAY
245–255: SAND with Gravelly SAND

*255–241: SLOUGH
241–211: BENTONITE
211–210: SAND
210–207: CEMENT PLUG
207–205: SLOUGH
205–203: BENTONITE PELLETS

NOTES: N/A: Not Applicable
INF: Insufficient Data



- Elevation of casing: INF
- Elevation of reference point: INF
- Concrete pad dimensions: Surface
- Depth of surface seal: INF
- Type of surface seal: INF
- I.D. of surface casing (if present): N/A
- Type of surface casing: N/A
- Depth of surface casing: N/A
- I.D. of riser pipe: 4–in.
- Type of riser pipe: Stainless Steel 16–in.,–90 10–in.,–202
- Diameter of borehole: 8–in.
- Diameter of perforated borehole casing: INF
- Type of filler: Granular bentonite & Bentonite slurry
- Elevation/depth of top of seal: INF
- Type of seal: Bentonite pellets
- Elevation/depth of top of gravel pack: INF
- Type of gravel pack: INF
- Elevation/depth of top of screen perforation: 191.0
- Description of screen/perforation: 8–in./10–slot/S.S. Telescoping/20–ft. removed 4–in.
- I.D. of screen section: 4–in.
- Elevation/depth of bottom of screen/perforation: 201.0
- Elevation/depth of bottom of gravel pack: 203.0
- Elevation/depth of bottom of plugged blank section: 203.0
- Type of filler below plugged section: N/A
- Elevation/depth of bottom of borehole: 203.0
- Elevation/depth of remediated borehole: N/A

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Figure D-1. Well 699-25-33A Construction and Completion Summary

Well Designation SM-5

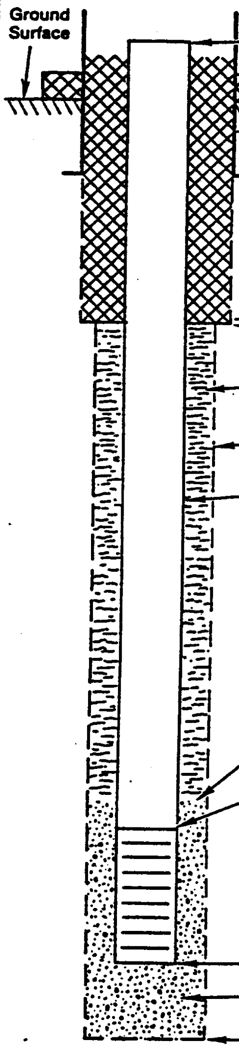
Hanford Well Number 699-25-34B

Hanford Coordinates N25,221.61 W33,551.98 Lambert Coordinates N430,437.42 E2,261,708.39

Date Completed 9/5/86

Well Construction Summary

All depths are from ground surface (no scale given)



Elevation of surface casing	529.65'
Elevation of reference point	529.15
Elevation of surveyor's pin	527.26'
Ground surface elevation	526.92'
Type of surface seal	Cement w/5% bentonite
Depth of surface seal	20'
Depth of surface casing	2'
I.D. of surface casing	10"
Type of surface casing	Schedule 40 carbon steel
Depth of original starter casing	20'
Depth of filler (seal)	20'
Type of filler	Granular bentonite
Diameter of borehole	8"
I.D. of riser pipe	5"
Type of riser pipe:	Schedule 40 carbon steel with vented locking cap
Depth of top of sand pack	115'
Type of sand pack:	Monterey crystal sand
Depth of top of screen	118.17'
Description of screen	
Length: 20' I.D. of screen section	5"
Slot size	Upper 10' #20, Lower 10' #25
Screen construction	Type 304 stainless steel continuous slot
Depth of bottom of screen	138.17'
Type of filler below Screen:	Monterey crystal sand
Depth of bottom of borehole	139.27'

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Figure D-2. Well 699-25-34B Construction and Completion Summary

WELL SUMMARY SHEET

Boring or Well No. 699-25-34D
Sheet 1 of 2

Location NRDWL #1
Project W017H
Elevation
Drilling Contractor JENSEN DRILLING.
Driller D. MINGO, S. MacKinnon
Drilling Method and Equipment Air Rotary / CP 650
Prepared By Mark D Sweeney / Keith J. Swett (Sign/Print Name) Date 10-19-92 / 10-24-92
Reviewed By Edward C. Rafuse (Sign/Print Name) Date 10/26/92

CONSTRUCTION DATA

Description

12" ID CS casing set @ 7.8' no shoe

Portland cement grout 20 Ft to 8.6 Ft

Bentonite crumbles 8.6 Ft to 119.4 Ft

10" ID CS casing set @ 172.01. 0.89' shoe

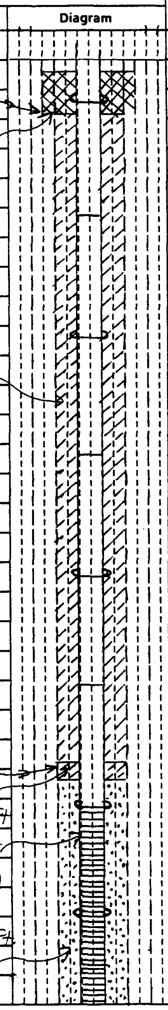
Enviroplug coarse chunk bentonite 119.4 Ft to 123.1 Ft

4" stainless steel .010 slot continuous wire wrap screen 126.80 Ft to 162.00 Ft.

Bolton centralizer @ 144.5 Ft

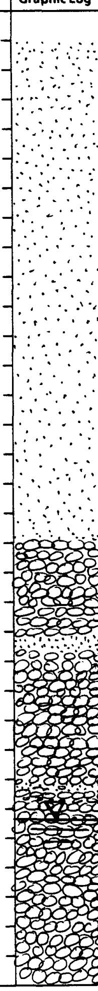
20-40 sand filter pack 123.1 Ft to 166.1 Ft

Diagram



GEOLOGIC/HYDROLOGIC DATA

Graphic Log



Depth in Feet	Lithologic Description
0	0-94 Sand
5	"
10	"
15	"
20	"
25	"
30	"
35	"
40	"
45	"
50	"
55	"
60	"
65	"
70	"
75	"
80	"
85	84-101 Gravel
90	"
95	"
100	101-103 Sand
105	"
110	"
115	103-126 Gravel
120	126-126.5 Silty Sandy Gravel
125	" " "
130	SWL = 132.37 Ft on
135	10-22-92 " " "
140	" " "
145	" " "
150	" " "
155	" " "
160	

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Figure D-3. Well 699-25-34D Construction and Completion Summary (1 of 2)

WELL SUMMARY SHEET

Boring or Well No. 699-25-34D

Sheet 2 of 2

Location NRDWL #1 | Project W017H
Elevation | Drilling Contractor Jensen Drilling
Driller D. Mingo, S. MacKinnon | Drilling Method and Equipment Air Rotary / CP-650
Prepared By Mark D Sweeney / Keith J. Sw (Sign/Print Name) Date 10-19-92 10-24-92 | Reviewed By Edward C. Rafuse (Sign/Print Name) Date 10/26/92

CONSTRUCTION DATA Description	Diagram	Depth in Feet	Graphic Log	GEOLOGIC/HYDROLOGIC DATA Lithologic Description
4"ø stainless steel .010 slot		165		161 - 173' Silty Sandy Gravel.
continuous wire wrap		170		" " "
screen 126.80 Ft to 162.00 FT		175		
20-40 sand Filterpack				
123.1 Ft to 166.1 Ft				
10"ø Temporary CS casing				
set at 172.01 Ft.				
(w/shoe)				
slough 166.1 Ft to 173.0 Ft				
TD = 173.00 Ft				

A-6000-384 (04/90)

Figure D-3. Well 699-25-34D Construction and Completion Summary (2 of 2)

WELL SUMMARY SHEET		Start Date: 7/22/2015 Finish Date: 9/08/2015	Page 1 of 2
Well ID: C9405		Well Name: 699-25-34F	
Location: 5 m E of NRDWL		Project: Installation of 4 Wells at NRDWL & SWL	
Prepared By: Tracy Mallgren	Date: 9/15/15	Reviewed By: J.D. MEHRER	Date: 9-30-15
Signature:		Signature:	

CONSTRUCTION DATA

Description

Concrete Pad: 0.50 ft above ground surface (ags)

6-in Protective Casing: 2.90 ft ags - 2.10 ft below ground surface (bgs)

Type I/II Portland Cement Grout: 0.00 - 9.30 ft bgs

3/8-in Cetco Medium Bentonite Chips: 9.30 - 120.06 ft bgs

4-in I.D. Schedule 10, Type 304/304L, Stainless Steel Blank Casing: 1.98 ft ags - 128.20 ft bgs

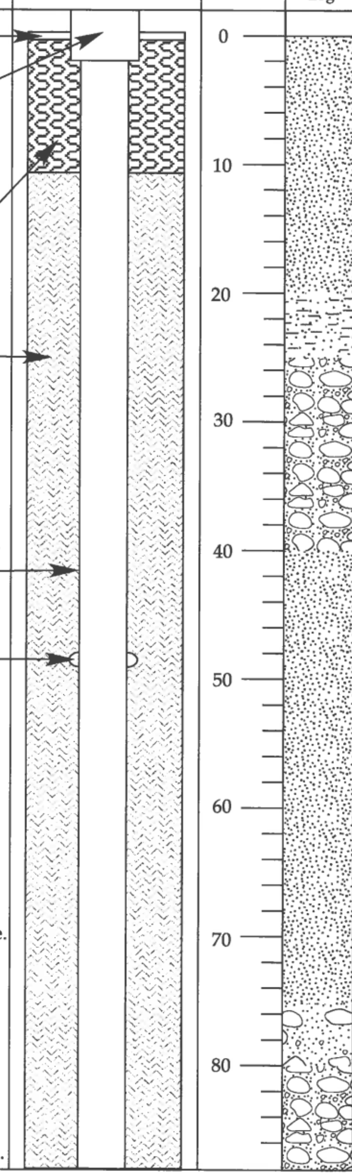
Stainless steel centralizer

Depths are in ft below ground surface.

Borehole drilled with:
9 1/4-in O.D. casing
from 0.00 - 100.40 ft bgs
and
8-in O.D. casing
from 100.40 - 164.50 ft bgs.

All temporary drill casing was removed from the ground.

Diagram | **Depth in Feet** | **Graphic Log**



GEOLOGIC/HYDROLOGIC DATA

Lithologic Description (ft bgs)

0 - 20 Sand (S)

20 - 25 Slightly Silty Sand ((m)S)

25 - 40 Gravelly Sand (gS)

40 - 75 Sand (S)

75 - 80 Gravelly Sand (gS)

80 - 120 Sandy Gravel (sG)

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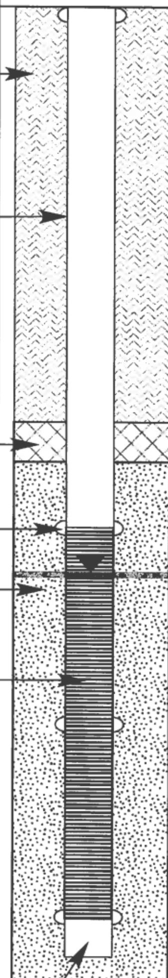
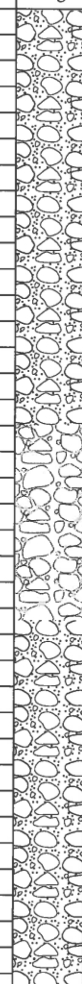
Figure D-4. Well 699-25-34F Construction and Completion Summary (1 of 2)

WELL SUMMARY SHEET		Start Date: 7/22/2015 Finish Date: 9/08/2015	Page 2 of 2
Well ID: C9405		Well Name: 699-25-34F	
Location: 5 m East of NRDWL		Project: Installation of 4 Wells at NRDWL & SWL	
Prepared By: Tracy Mallgren	Date: 9/15/15	Reviewed By: J.D. MEHRER	Date: 9-30-15
Signature:		Signature:	

CONSTRUCTION DATA

Description	Diagram
3/8-in Cetco Medium Bentonite Chips: 9.30 - 120.06 ft bgs 4-in I.D. Schedule 10, Type 304/304L, Stainless Steel Blank Casing: 1.90 ft ags - 128.20 ft bgs 3/8-in Cetco Coated Bentonite Pellet Seal: 120.06 - 122.90 ft bgs Stainless steel centralizer 8-16 mesh Premier Colorado Silica Filter Pack Sand: 122.90 - 163.00 ft bgs 4-in I.D. Schedule 10, Type 304/304L, 40-slot (0.040 in.) Stainless Steel Screen: 128.20 - 158.21 ft bgs Depths are in ft below ground surface. Borehole drilled with: 9 1/4-in O.D. casing from 0.00 - 100.40 ft bgs and 8-in O.D. casing from 100.40 - 164.50 ft bgs. All temporary drill casing was removed from the ground. 4-in I.D. Schedule 10, Type 304/304L, Stainless Steel Sump: 158.21 - 161.21 ft bgs	

GEOLOGIC/HYDROLOGIC DATA

Depth in Feet	Graphic Log	Lithologic Description (ft bgs)
90		80 - 120 Sandy Gravel (sG)
100		
110		
120		120 - 135 Gravel (G)
130		Static Water Level: 131.8 ft bgs (8/05/15)
		135 - 163 Sandy Gravel (sG)
140		
150		
160		
		Total Depth: 163.0 ft bgs (8/05/2015)
		Straightness Test: Passed 8/5/2015
170		

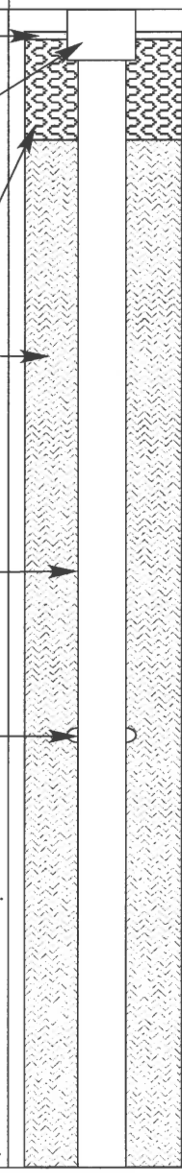
A-6003-643 (REV 1)

Figure D-4. Well 699-25-34F Construction and Completion Summary (2 of 2)

WELL SUMMARY SHEET		Start Date: 7/23/2015 Finish Date: 09/08/2015	Page 1 of 2
Well ID: C9404		Well Name: 699-26-33A	
Location: 5 m E of NRDWL (North End)		Project: Installation of 4 Wells at NRDWL & SWL	
Prepared By: Tracy Mallgren	Date: 9/14/15	Reviewed By: J.D. MEHRER	Date: 9/29/15
Signature:		Signature:	

CONSTRUCTION DATA

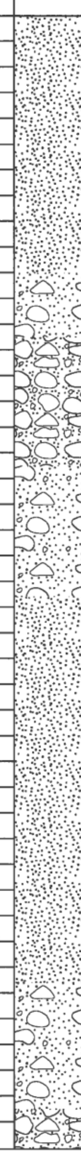
Description	Diagram
Concrete Pad: 0.50 ft above ground surface (ags)	
6-in Protective Casing: 3.25 ft ags - 1.75 ft below ground surface (bgs)	
Type I/II Portland Cement Grout: 0.00 - 8.00 ft bgs	
3/8-in Cetco Medium Bentonite Chips: 8.00 - 126.00 ft bgs	
4-in I.D. Schedule 10, Type 304/304L, Stainless Steel Blank Casing: +2.27 ft ags - 133.73 ft bgs	
Stainless steel centralizers	
Depths are in ft below ground surface.	
Borehole drilled with: 9 1/4-in O.D. casing from 0.00 - 100.40 ft bgs and 8-in O.D. casing from 100.40 - 169.50 ft bgs.	
All temporary drill casing was removed from the ground.	



GEOLOGIC/HYDROLOGIC DATA

Depth in Feet: 0, 10, 20, 30, 40, 50, 60, 70, 80

Graphic Log



Lithologic Description (ft bgs)
0 - 20 Sand (S)
20 - 25 Gravelly Sand (gS)
25 - 35 Sandy Gravel (sG)
35 - 45 Gravelly Sand (gS)
45 - 75 Sand (S)
75 - 85 Gravelly Sand (gS)
85 - 95 Sandy Gravel (sG)

A-6003-643 (REV 1)

Figure D-5. Well 699-26-33A Construction and Completion Summary (1 of 2)

WELL SUMMARY SHEET	Start Date: 07/23/2015	Page 2 of 2
	Finish Date: 09/08/2015	

Well ID: C9404	Well Name: 699-26-33A	
Location: 5 m East of NRDWL (North End)	Project: Installation of 4 Wells at NRDWL & SWL	
Prepared By: Tracy Mallgren — Date: 9/14/15	Reviewed By: J.D. MEHRER	Date: 9/29/15
Signature:	Signature:	

CONSTRUCTION DATA — Description

Stainless steel centralizer

4-in I.D. Schedule 10, Type 304/304L, Stainless Steel Blank Casing: +2.27 ft ags - 133.73 ft bgs

3/8-in Cetco Medium Bentonite Chips: 8.00 - 126.00 ft bgs

3/8-in Cetco Coated Bentonite Pellet Seal: 126.00 - 130.00 ft bgs

8-16 mesh Premier Colorado Silica Filter Pack Sand: 130.00 - 168.70 ft bgs

4-in I.D. Schedule 10, Type 304/304L, 40-slot (0.040 in.) Stainless Steel Screen: 133.73 - 163.73 ft bgs

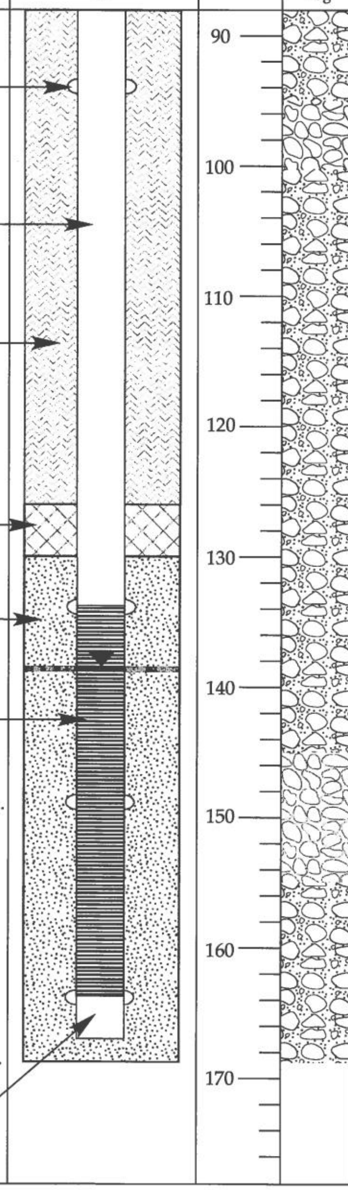
Depths are in ft below ground surface.

Borehole drilled with:
9 1/4-in O.D. casing
from 0.00 - 100.40 ft bgs
and
8-in O.D. casing
from 100.40 - 169.50 ft bgs.

All temporary drill casing was removed from the ground.

4-in I.D. Schedule 10, Type 304/304L, Stainless Steel Sump: 163.73 - 166.73 ft bgs

Diagram | Depth in Feet | Graphic Log



GEOLOGIC/HYDROLOGIC DATA — Lithologic Description (ft bgs)

85 - 95 Sandy Gravel (sG)

95 - 100 Gravel (G)

100 - 145 Sandy Gravel (sG)

Static Water Level: 137.5 ft bgs (9/3/15)

145 - 155 Gravel (G)

155 - 169 Sandy Gravel (sG)

Total Depth: 168.7 ft bgs (8/13/2015)

Straightness Test: Passed 8/12/2015

A-6003-643 (REV 1)

Figure D-5. Well 699-26-33A Construction and Completion Summary (2 of 2)

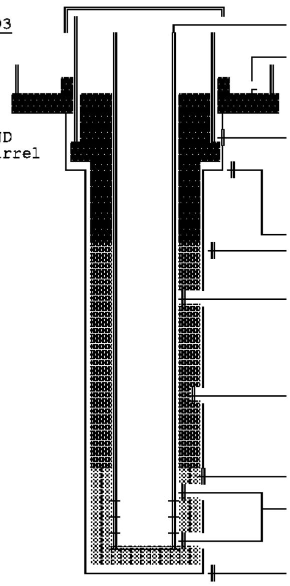
WELL CONSTRUCTION AND COMPLETION SUMMARY

Drilling Method: Cable tool	Sample Method: Drive barrel Hard tool	WELL NUMBER: 699-26-34A A5102 TEMPORARY WELL NO: SM-2
Drilling Fluid Used: Water	Additives Used: None documented	Hanford Coordinates: N/S N 26,162.95 E/W W 34,483.26
Driller's Name: Evans/Myrick(s)	WA State Lic Nr: Not documented	State Coordinates: N 431,376.37 E 2,260,774.69
Drilling Company: Myrick's Well Drill.	Company Location: Not documented	Start Card #: Not documented T____ R____ S______
Date Started: 22May86	Date Complete: 03Jul86	Elevation Ground surface: 526.43 Brass cap

Depth to water: 121.5-ft Jun86
(Ground surface) 125.0-ft 27Dec93

GENERALIZED Driller's STRATIGRAPHY Log

0-75: Not documented
75-81: Large GRAVEL and fine SAND
81-120: Not documented, drive barrel
120-136: BOULDER or BOULDERS
136-143: SAND (heaving)



Elevation of reference point: [528.11-ft]
(top of 5-in casing)
Height of reference point above [1.7-ft]
ground surface
Depth of surface seal [0-20-ft]
Type of surface seal:
Cement grout w/5% bentonite to 20-ft
4-ft x 4-ft x 4-in concrete pad
with 2-ft round pad supporting
10-in ID carbon steel protective
casing to 17-ft

11-in nominal hole, 0-20-ft
9-in nominal hole, 20-143-ft

5-in ID sch 40 carbon steel casing,
+1.7-117.2-ft

Granular bentonite, 20-114.2-ft

Monterey crystal sand pack,
114.2-143.0-ft, mesh not documented

5-in stainless steel screen,
117.2-127.2-ft, #20-slot
127.2-137.2-ft, #25 slot

Borehole drilled depth: [143.0-ft]

Drawing By: RKL/6N26W34A.ASB
Date : 14Sep94
Reference : HANFORD WELLS

Figure D-6. Well 699-26-34A Construction and Completion Summary (1 of 2)

```
                    SUMMARY OF CONSTRUCTION DATA AND FIELD OBSERVATIONS
                           RESOURCE PROTECTION WELL - 699-26-34A

WELL DESIGNATION     :   699-26-34A
RCRA FACILITY        :   Central Landfill
CERCLA UNIT          :   Not applicable
HANFORD COORDINATES  :   N   26,162.95  W    34,483.26 [29Jul86-200E]
LAMBERT COORDINATES  :   N  431,376.37  E 2,260,774.69 [11Nov86-WA S]
DATE DRILLED         :   Jul86
DEPTH DRILLED  (GS)  :   143.0-ft
MEASURED DEPTH (GS)  :   Not documented
DEPTH TO WATER (GS)  :   121.5-ft, Jun86
                         125.0-ft, 27Dec93
CASING DIAMETER      :   10-in, carbon steel, +2.0-17.0-ft
                          5-in, carbon steel, +1.7-117.2-ft
ELEV TOP CASING      :   528.11-ft, (5-in)     [10May91-NGVD'29]
                         528.40-ft, (10-in)    [10May91-NGVD'29]
ELEV GROUND SURFACE  :   526.40-ft, Brass cap [10May91-NGVD'29]
PERFORATED INTERVAL  :   Not applicable
SCREENED INTERVAL    :   117.2-137.2-ft, 5-in stainless steel,
                          117.2-127.2-ft, #20-slot,
                          127.2-137.2-ft, #25-slot,
COMMENTS             :   FIELD INSPECTION, 25Jun91,
                         10 and 5-in carbon steel casings. Capped and locked
                         4-ft x 4-ft pad with 2-ft pad supporting 10-in casing,
                         no posts, has well identification stamped on brass marker in pad.
                         Not in radiation zone.
                         OTHER;
AVAILABLE LOGS       :   Driller
TV SCAN COMMENTS     :   Not applicable
DATE EVALUATED       :   Not applicable
EVAL RECOMMENDATION  :   Not applicable
LISTED USE           :   WHC sitewide semiannual water level measurement, 01Apr88-27Dec93;
CURRENT USER         :   WHC ES&M RCRA sampling and w/l monitoring,
                         PNL sitewide sampling
PUMP TYPE            :   Electric submersible
MAINTENANCE          :
```

Figure D-6. Well 699-26-34A Construction and Completion Summary (2 of 2)

WELL SUMMARY SHEET

Boring or Well No. 699-26-34B

Sheet 1 of 2

Location NRDWL #2

Project W017H

Elevation

Drilling Contractor JENSEN DRILLING

Driller D MINGO S. MACKINNON

Drilling Method and Equipment AIR ROTARY / CP 650

Prepared By MOSWETNEY / [signature] Date 10-14-92

K.J. SWETT (Sign/Print Name) [signature] 10-24-92

Reviewed By EDWARD C. RAFUSE / Edward C. Rafuse (Sign/Print Name) Date 10/26/92

CONSTRUCTION DATA: Description	Depth in Feet	GEOLOGIC/HYDROLOGIC DATA: Lithologic Description
12" ID RTS 10-24-92 12" OD TEMPORARY CASING	0	0-74 SAND
SET 8.53' NO SHOE	5	"
	10	"
Portland Cement GROUT	15	"
1.5 Ft to 8.2 Ft	20	"
	25	"
10" Dia Temporary CS	30	"
casing w/shoe set at	35	"
161.98 FT	40	"
	45	"
Bentonite Crumbles	50	"
8.2 Ft to 111.0 Ft	55	"
	60	"
	65	"
	70	"
	75	74-82 GRAVEL
	80	"
	85	82-85 SANDY GRAVEL
	90	85-87 GRAVEL
	95	"
Enviroplug coarse	100	87-99 GRAVELLY SAND
chunk bentonite	105	99-102 GRAVEL
111.0 Ft to 115.2 Ft	110	102-108 SANDY GRAVEL
	115	SWL = 124.12 Ft 10-23-92
4" ø stainless steel	120	108-119 SAND.
.010 slot continuous	125	119-122 GRAVELLY SAND 122-124 SAND 124-127 SANDY GRAVEL
wire wrap screen	130	" "
118.37 Ft to 153.57 Ft.	135	
w/ Bolt on centralizer @	140	127-139 SILTY SANDY GRAVEL
136.0 Ft.	145	" " "
	150	" " "
20-40 sand filter pack	155	" " "
115.2 Ft to 161.6 Ft	160	139-164.93 PEBBLE COBBLE GRAVEL

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Figure D-7. Well 699-26-34B Construction and Completion Summary (1 of 2)

WELL SUMMARY SHEET

Boring or Well No. 699-26-34B
Sheet 2 of 2

Location NRDWL #2
Project W017H
Elevation
Drilling Contractor JENSEN DRILLING
Driller D. Minko S. MacKinnon
Drilling Method and Equipment Air Rotary / CP-650
Prepared By MASweeney / K.J. Swett (Sign/Print Name) Date 10-16-92 10-24-92
Reviewed By Edward C. Rafuse (Sign/Print Name) Date 10/26/92

CONSTRUCTION DATA		Depth in Feet	GEOLOGIC/HYDROLOGIC DATA	
Description	**Diagram**		**Graphic Log**	**Lithologic Description**
10" Dia Temporary CS casing				" " "
w/shoe set at 161.98 Ft		165		
20-40 sand filterpack				
115.2 Ft to 161.6 Ft				
slough 161.6 Ft to				
164.93 FT				
TD = 164.93 Ft				

A-6000-384 (04/90)

Figure D-7. Well 699-26-34B Construction and Completion Summary (2 of 2)

A5103 / 699-26-35A

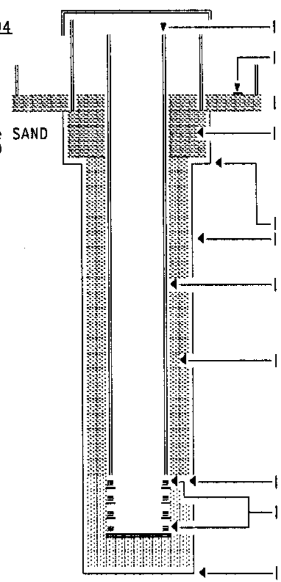
WELL CONSTRUCTION AND COMPLETION SUMMARY

Drilling Method: Cable tool	Sample Method: Drive barrel Hard tool	WELL NUMBER: 699-26-35A A5103 TEMPORARY WELL NO: SM-1
Drilling Fluid Used: Water	Additives Used: Bentonite	Hanford Coordinates: N/S N 25,768.80 E/W W 34,748.81
Driller's Name: Myricks(s)	WA State Lic Nr: Not documented	State Coordinates: N 430,981.54 E 2,260,510.15
Drilling Company: Myrick's Well Drill.	Company Location: Not documented	Start Card #: Not documented T____ R____ S______
Date Started: 20May86	Date Complete: 14Jul86	Elevation Ground surface: 530.38 Brass cap

Depth to water: 126.5-ft Jun86
(Ground surface) 129.7-ft 20Jun94

GENERALIZED Driller's
STRATIGRAPHY Log

0↔38: Not documented
38↔69: 90% coarse SAND, 10% fine SAND
69↔70: 20% GRAVEL, 80% fine SAND
70↔95: Not documented
95↔114: BOULDERS
114↔120: GRAVEL
120↔130: GRAVEL & SAND
130↔152.5: SAND & GRAVEL



Elevation of reference point: [532.38-ft]
(top of 5-in casing)
Height of reference point above [2.0-ft]
ground surface
Depth of surface seal [0↔20-ft]
Type of surface seal:
Cement grout w/5% bentonite to 20-ft
4-ft x 4-ft x 4-in concrete pad
with 2-ft round pad supporting
10-in ID carbon steel protective
casing to 2-ft
11-in nominal hole, 0↔20-ft
9-in nominal hole, 20↔152.5-ft
5-in ID sch 40 carbon steel casing,
+2.0↔120.4-ft
Granular bentonite, 20↔120.5-ft
Monterey crystal sand pack,
120.5↔152.5-ft, mesh not documented
5-in stainless steel screen,
120.4↔130.4-ft, #20-slot
130.4↔140.4-ft, #25-slot
Borehole drilled depth: [152.5-ft]

Drawing By: RKL/6N26W35A.ASB
Date : 14Sep94
Reference : HANFORD WELLS

Figure D-8. Well 699-26-35A Construction and Completion Summary (1 of 2)

SUMMARY OF CONSTRUCTION DATA AND FIELD OBSERVATIONS
RESOURCE PROTECTION WELL - 699-26-35A

WELL DESIGNATION	:	699-26-35A
RCRA FACILITY	:	Central Landfill
CERCLA UNIT	:	Not applicable
HANFORD COORDINATES	:	N 25,768.80 W 34,748.81 [29Jul86-200E]
LAMBERT COORDINATES	:	N 430,981.54 E 2,260,510.15 [11Nov86-WA S]
DATE DRILLED	:	Jul86
DEPTH DRILLED (GS)	:	152.5-ft
MEASURED DEPTH (GS)	:	130.3-ft, 25Jun91
DEPTH TO WATER (GS)	:	126.5-ft, Jun86 129.7-ft, 20Jun94
CASING DIAMETER	:	10-in, carbon steel, +2.3↔2.0-ft, 5-in, carbon steel, +2.0↔120.4-ft
ELEV TOP CASING	:	532.38-ft, (5-in) [10May91-NGVD'29] 532.66-ft, (10-in) [10May91-NGVD'29]
ELEV GROUND SURFACE	:	530.38-ft, Brass cap [10May91-NGVD'29]
PERFORATED INTERVAL	:	Not applicable
SCREENED INTERVAL	:	120.4↔140.4-ft, 5-in stainless steel, 120.4↔130.4-ft, #20-slot, 130.4↔140.4-ft, #25-slot,
COMMENTS	:	FIELD INSPECTION, 25Jun91, 10 and 5-in carbon steel casings. Capped and locked 4-ft x 4-ft pad with 2-ft pad supporting 10-in casing, no posts, has well identification stamped on brass marker in pad. Not in radiation zone. OTHER;
AVAILABLE LOGS	:	Driller
TV SCAN COMMENTS	:	Not applicable
DATE EVALUATED	:	Not applicable
EVAL RECOMMENDATION	:	Not applicable
LISTED USE	:	WHC Central Landfill monthly water level measurement, 01Apr88↔20Jun94;
CURRENT USER	:	WHC ES&M RCRA sampling and w/l monitoring, PNL sitewide sampling
PUMP TYPE	:	Hydrostar
MAINTENANCE	:	

Figure D-8. Well 699-26-35A Construction and Completion Summary (2 of 2)

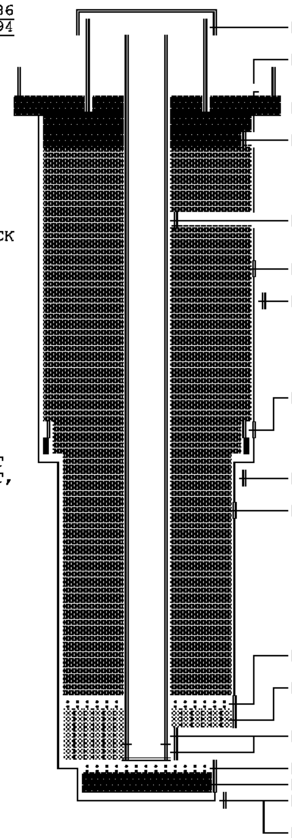
WELL CONSTRUCTION AND COMPLETION SUMMARY

Drilling Method: Cable tool	Sample Drive barrel Method: Hard tool	WELL NUMBER: 699-26-35C A5104 TEMPORARY WELL NO: DM-1
Drilling Fluid Used: Water	Additives Used: None	Hanford Coordinates: N/S N 25,751.10 E/W W 34,688.94
Driller Name: L Myrick/R Myrick L Bultena	WA State Lic Nr: Not documented	State Coordinates: N 430,981.54 E 2,260,510.15
Drilling Company: Myrick Drilling Co Onwego Drilling Co	Company Location: Not documented Kennewick WA	Start Card #: Not documented T____ R____ S______
Date Started: 23Jun86	Date Complete: 05Jan87	Elevation Ground surface: 530.65-ft Brass cap

Depth to water: 127.0-ft 15Jul86
(Ground surface) 129.5-ft 20Jun94

GENERALIZED Driller's
STRATIGRAPHY Log

0-4: Very cse b&w SAND
15-20: Fine brown SAND
20-30: Cse black SAND
30-40: Fine brown & black SAND
40-50: Black cse SAND
50-55: Fine grey SAND
55-65: Fine brown SAND
65-75: Black & brown SAND, w/ROCK
75-80: Brown SAND
80-85: Large ROCK, some SAND
85-90: Round river run ROCK
90-100: BOULDERS, GRAVEL, SAND
100-110: Round ROCK
110-115: ROCK, GRAVEL & SAND
115-125: BOULDERS
125-135: Not documented
135-140: Fine SAND
140-145: Fine compacted SAND
145-155: Fine SAND, heaving
155-170: Cse GRAVEL-SAND
170-172: Loose COBBLES
172-203: GRAVEL, SAND, some SILT
203-204: GRAVEL, SAND, some SILT, CLAY
204-211: Not documented (Attempted to sample w/drive sampler and split spoon)



Drawing By: RKL/6N26W35C.ASB
Date : 14Sep94
Reference : HANFORD WELLS

Figure D-9. Well 699-26-35C Construction and Completion Summary (1 of 2)

SUMMARY OF CONSTRUCTION DATA AND FIELD OBSERVATIONS
RESOURCE PROTECTION WELL - 699-26-35C

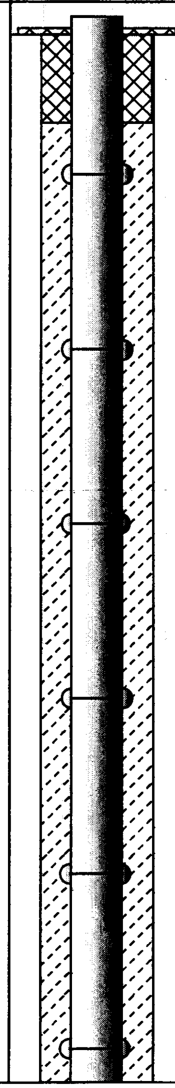
WELL DESIGNATION	:	699-26-35C
CERCLA UNIT	:	Not applicable
RCRA FACILITY	:	NRDW Landfill
HANFORD COORDINATES	:	N 25,751.10 W 34,688.94 [200E-21Jan87]
LAMBERT COORDINATES	:	N 430,981.54 E 2,260,510.15 [LAMBERT-21Jan87]
DATE DRILLED	:	Jan87
DEPTH DRILLED (GS)	:	211.0-ft
MEASURED DEPTH (GS)	:	Not documented
DEPTH TO WATER (GS)	:	127.0-ft, 15Jul86 129.5-ft, 20Jun94
CASING DIAMETER	:	4-in stainless steel, +1.5-193.0-ft 8-in carbon steel, +2.0--0.5-ft
ELEV TOP CASING	:	532.68-ft, [10May91-NGVD'29]
ELEV GROUND SURFACE	:	530.65-ft, Brass cap [10May91-NGVD'29]
PERFORATED INTERVAL	:	Not applicable
SCREENED INTERVAL	:	193.0-203.0-ft, 4-in #20-slot stainless steel;
COMMENTS	:	FIELD INSPECTION, 27Aug92; 8-in carbon steel casing 4-ft by 4-ft concrete pad no posts. Capped and locked, brass cap in pad with well ID. Not in radiation zone. OTHER:
AVAILABLE LOGS	:	Driller
TV SCAN COMMENTS	:	Not applicable
DATE EVALUATED	:	Not applicable
EVAL RECOMMENDATION	:	Not applicable
LISTED USE	:	Central landfill monthly water level measurement, 27Aug90-20Jun94,
CURRENT USER	:	WHC ES&M w/l monitoring and RCRA sampling,
PUMP TYPE	:	Electric submersible
MAINTENANCE	:	

Figure D-9. Well 699-26-35C Construction and Completion Summary (2 of 2)

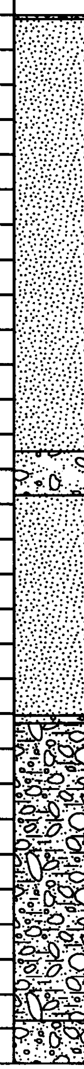
WELL SUMMARY SHEET	Start Date: 1/20/2014	Page 1 of 2
	Finish Date: 2/26/2014	

Well ID: C8774		Well Name: 699-26-38	
Location: W. of Central Landfill		Project: 3 Wells -- M-24 Project	
Prepared by: Julie Johanson	Date: 3/4/2014	Reviewed by: D. MEHRER	Date: 4-2-14
Signature: Julie Johanson		Signature: [signature]	

CONSTRUCTION DATA

Description	Diagram
Surface Completion: 4'x4'x6" Concrete Pad w/brass survey marker and 6 5/8" protective monument 2.90' ags. Well Completion Materials: High Strength Concrete 0.0' bgs - 0.4' bgs Type I/II Portland Cement 0.4' bgs - 10.9' bgs Medium Bentonite Chips 10.9' bgs - 129.3' bgs 1/4" Bentonite Pellets 129.3' bgs - 131.8' bgs 10x20 Colorado Silica Sand 131.8' bgs - 169.0' bgs Natural Fill 169.0' bgs - 169.9' bgs Permanent Well: 4 1/2" OD Stainless Steel Blank 2.02' ags - 136.13' bgs 4 1/2" OD Stainless Steel 0.040 Slot Screen 136.13' bgs - 166.12' bgs 4 1/2" OD Stainless Steel Sump 166.12' bgs - 169.12' bgs All temporary casing completely removed from ground (2/11/2014). bgs = below ground surface ags = above ground surface	

GEOLOGIC/HYDROLOGIC DATA

Depth in Feet	Graphic Log	Lithologic Description
0–120 (scale: 0, 20, 40, 60, 80, 100)		0 - 0.5: Gravel Pad; Silty Sandy Gravel (msG) 0.5 - 50: Sand (S) 50 - 55: Gravelly Sand (gS) 55 - 80: Sand (S) 80 - 81: Gravelly Sand (gS) 81 - 115: Silty Sandy Gravel (msG) 115 - 130: Sandy Gravel (sG)

A-6003-643 (03/03)

Figure D-10. Well 699-26-38 Construction and Completion Summary (1 of 2)

WELL SUMMARY SHEET		Start Date: 1/20/2014 Finish Date: 2/26/2014	Page 2 of 2
Well ID: C8774		Well Name: 699-26-38	
Location: W. of Central Landfill		Project: 3 Well -- M-24 Project	
Prepared by: Julie Johanson	Date: 3/4/2014	Reviewed by: J.D. MEHRER	Date: 4-2-14
Signature: Julie Johanson		Signature: [signature]	

CONSTRUCTION DATA

Description

Well Completion Material:
High Strength Concrete
0.0' bgs - 0.4' bgs

Type I/II Portland Cement
0.4' bgs - 10.9' bgs

Medium Bentonite Chips
10.9' bgs - 129.3' bgs

1/4" Bentonite Pellets
129.3' bgs - 131.8' bgs

10x20 Colorado Silica Sand
131.8' bgs - 169.0' bgs

Natural Fill
169.0' bgs - 169.9' bgs

Permanent Well:
4 1/2" OD Stainless Steel Blank
2.02' ags - 136.13' bgs

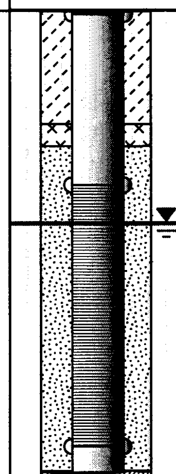
4 1/2" OD Stainless Steel 0.040 Slot Screen
136.13' bgs - 166.12' bgs

4 1/2" OD Stainless Steel Sump
166.12' bgs - 169.12' bgs

All temporary cassing completely removed from ground (2/11/2014)

bgs = below ground surface
ags = above ground surface

Diagram



GEOLOGIC/HYDROLOGIC DATA

Depth in Feet	Graphic Log	Lithologic Description
120		115 - 130: Sandy Gravel (sG)
		130 -149: Silty Sandy Gravel (msG)
140		DTW: 140.48' bgs
		149 -159: Sandy Gravel (sG)
		159 -160: Sand (S)
160		160 -165: Sandy Gravel (sG)
		165 -166: Sitly Sandy Gravel (msG)
		166 - 167: Silty Gravel (mG)
		167 - 169.9: Silty Sandy Gravel (msG)
180		TD: 169.9' bgs

A-6003-643 (03/03)

Figure D-10. Well 699-26-38 Construction and Completion Summary (2 of 2)

D2 Reference

NAVD88, 1988, *North American Vertical Datum of 1988*, as revised, National Geodetic Survey, Federal Geodetic Control Committee, Silver Spring, Maryland. Available at: http://www.ngs.noaa.gov/.

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Appendix E

Statistical Method Determination

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Contents

Figures

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E1 Introduction

An accelerated sampling program will be conducted to obtain a minimum of eight samples. The accelerated sampling program will monitor the constituents listed in Table 9-4 (Appendix 5 of Ecology Publication No. 97-407, *Chemical Test Methods For Designating Dangerous Waste WAC 173-303-090 & -100*) of the main text at a quarterly frequency for 2 years. After 2 years of sampling is completed, the statistical test method can be determined using the flowcharts presented in this appendix.

The flowcharts (Figures E-1 through E-7) represent a series of statistical analyses, consistent with EPA 530/R-09-007, *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities Unified Guidance*, that describe basic methodology for determining the type of statistical test that would be most appropriate for implementation in a groundwater monitoring plan for regulated waste. These flowcharts guide the user through tests to identify potential outliers and evaluate statistical distributions, spatial variance, temporal trends, and equality of variance for background and compliance wells. EPA 530/R-09-007 should be consulted for conditional data handling requirements related to normality of distribution for Rosner’s, Modified Dixson’s, and analysis of variance (ANOVA) tests. Based on these series of tests, the user is directed towards the type of test, interwell or intrawell, that is most appropriate based on the available data. The flowcharts do not proclaim to provide every detail of every process but are to be used as a guide.

Figure E-8 provides a chart legend applicable to Figures E-1 through E-7.

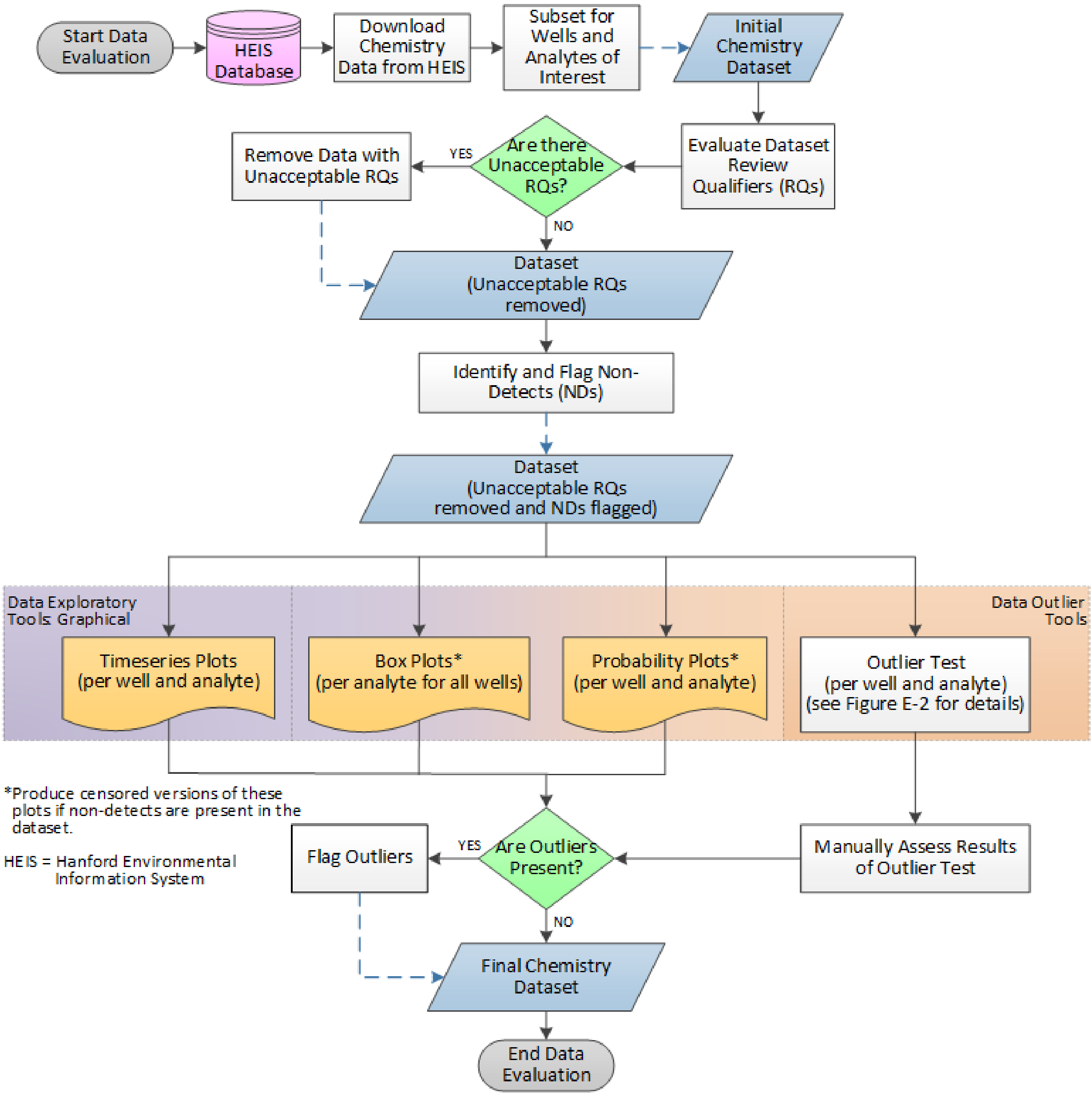

Figure E-1. Data Evaluation

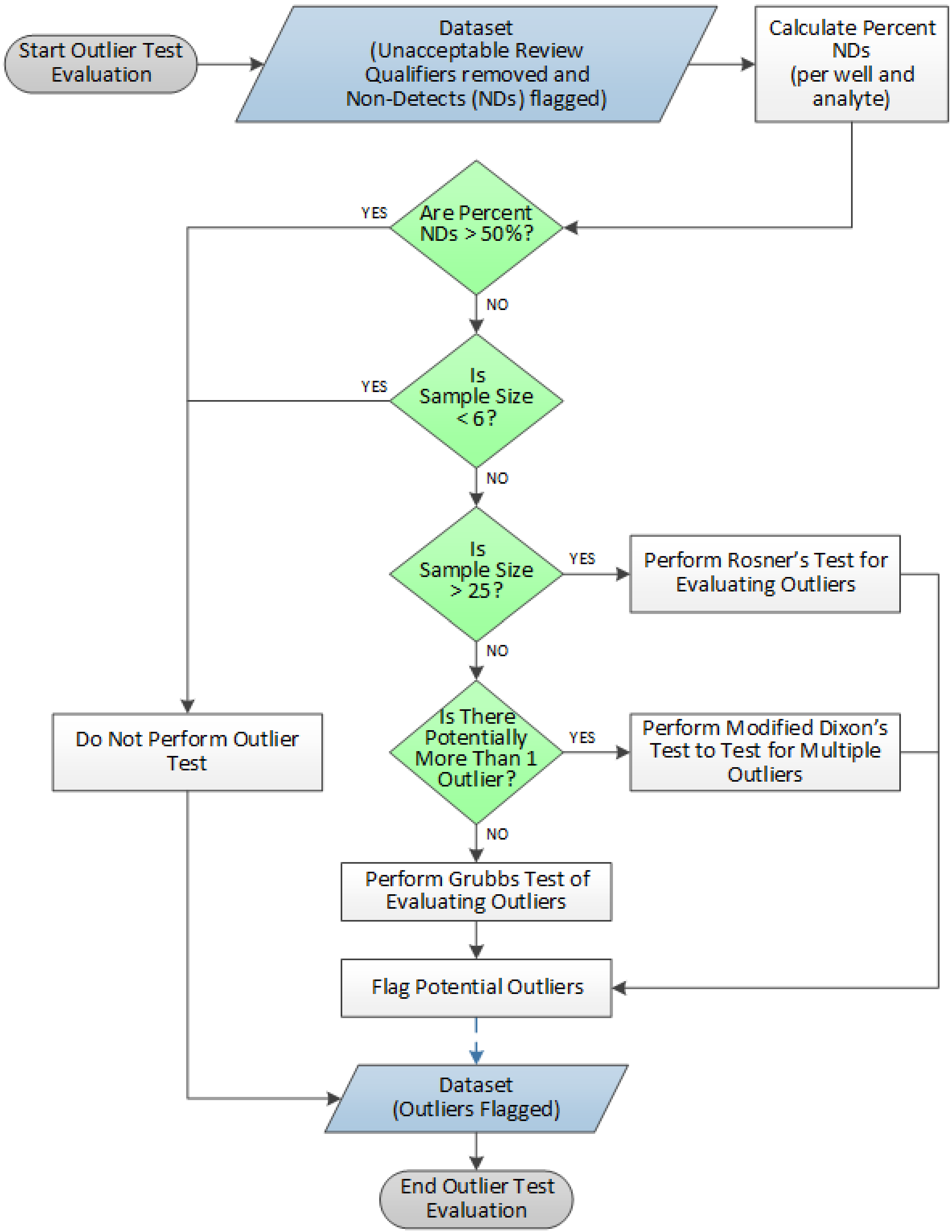

Figure E-2. Outlier Test Evaluation

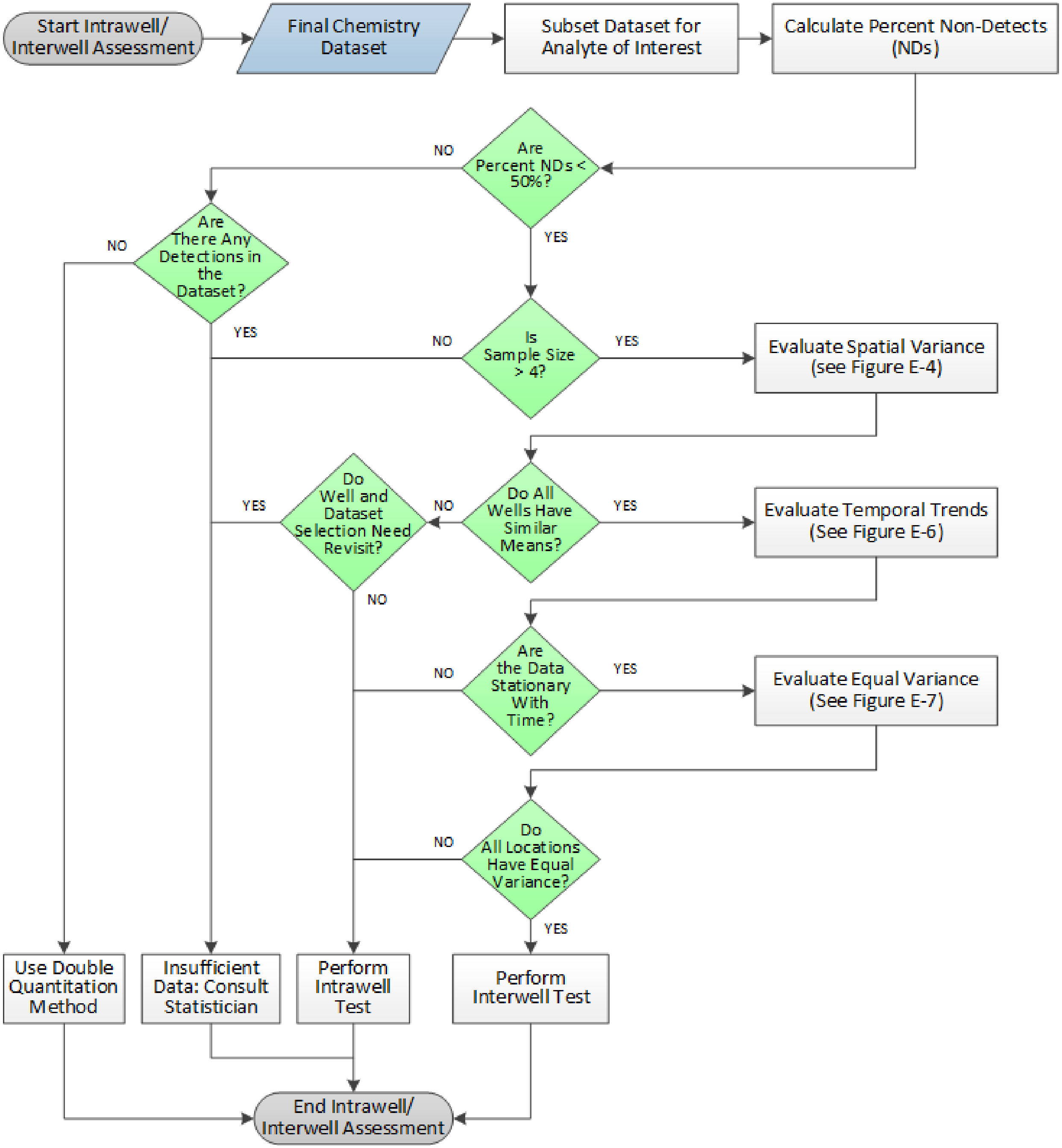

Figure E-3. Intrawell/Interwell Assessment

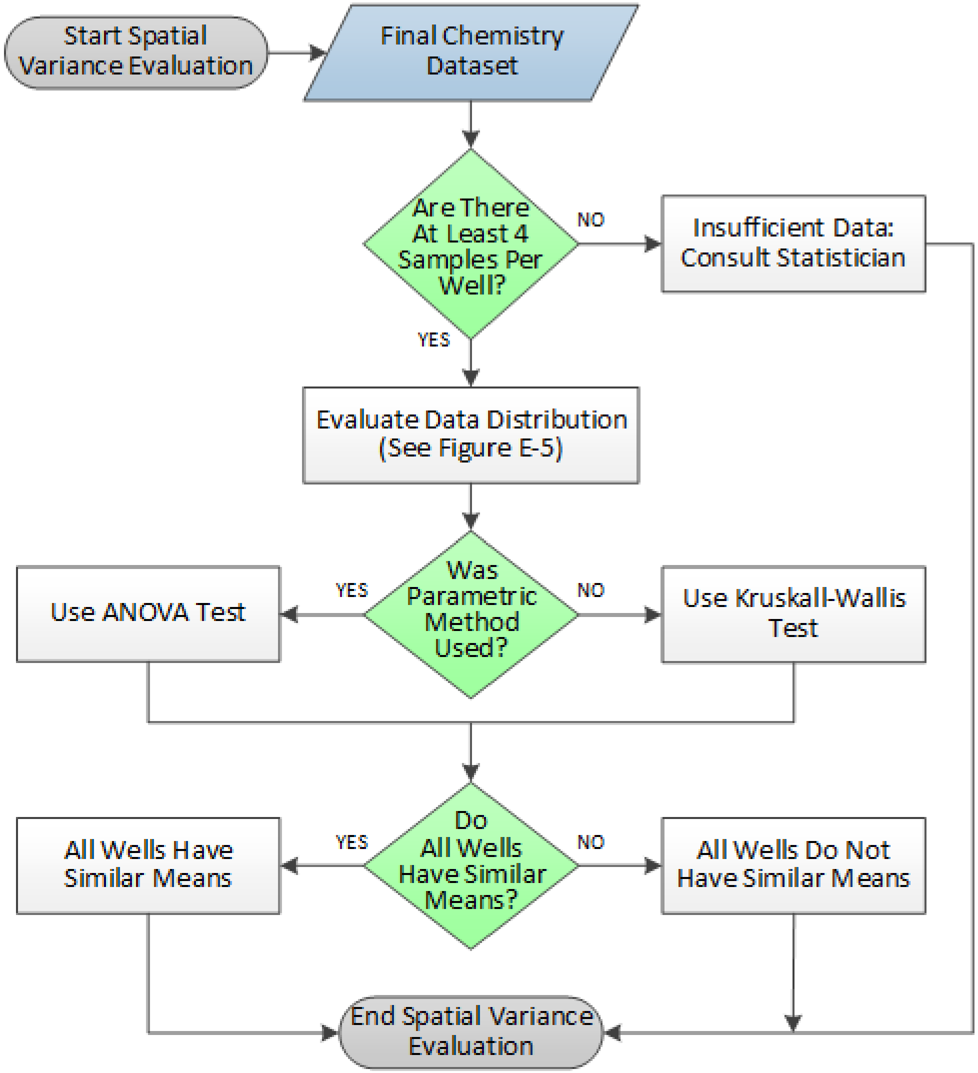

Figure E-4. Spatial Variance Evaluation

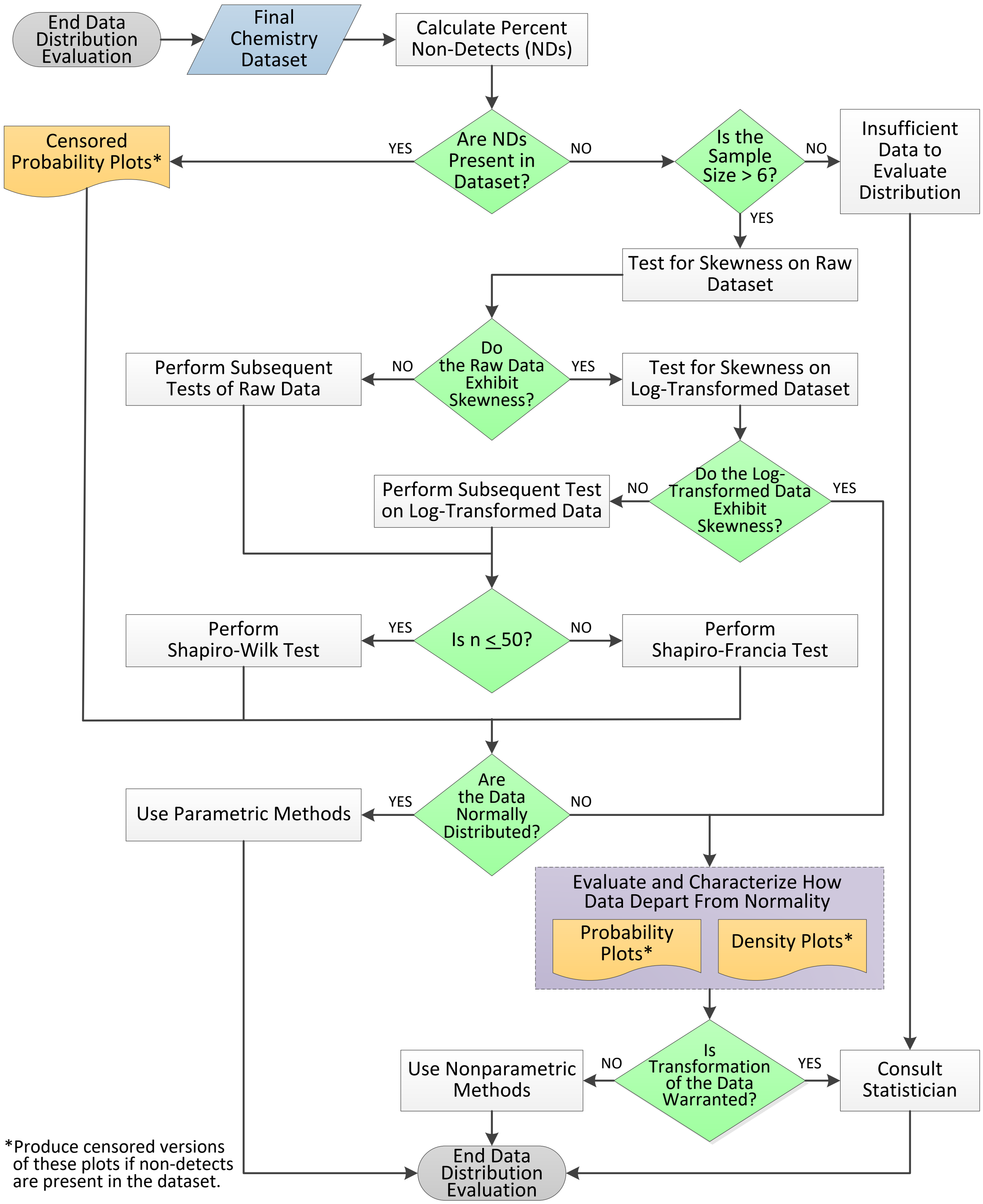

Figure E-5. Data Distribution Evaluation

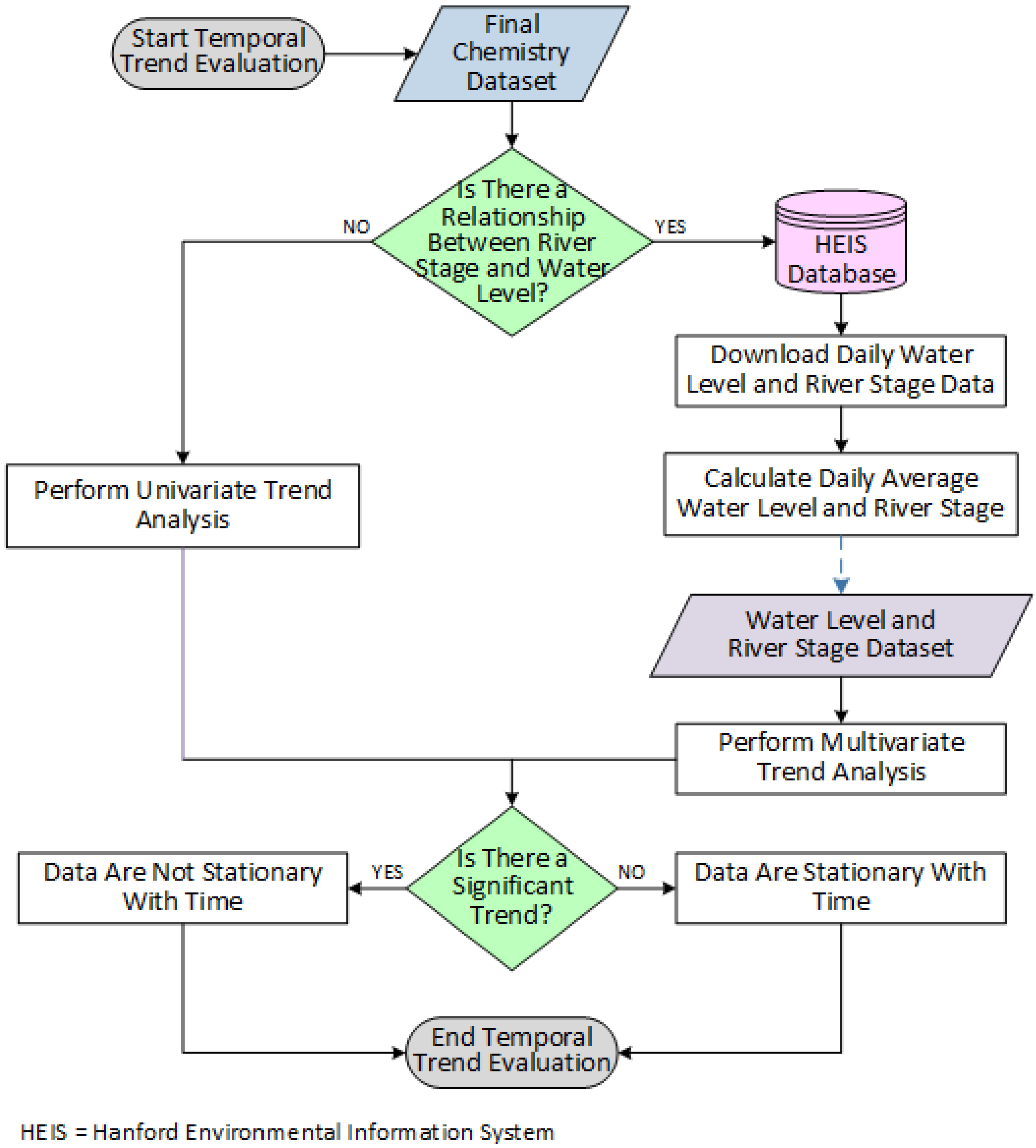

Figure E-6. Temporal Trend Analysis

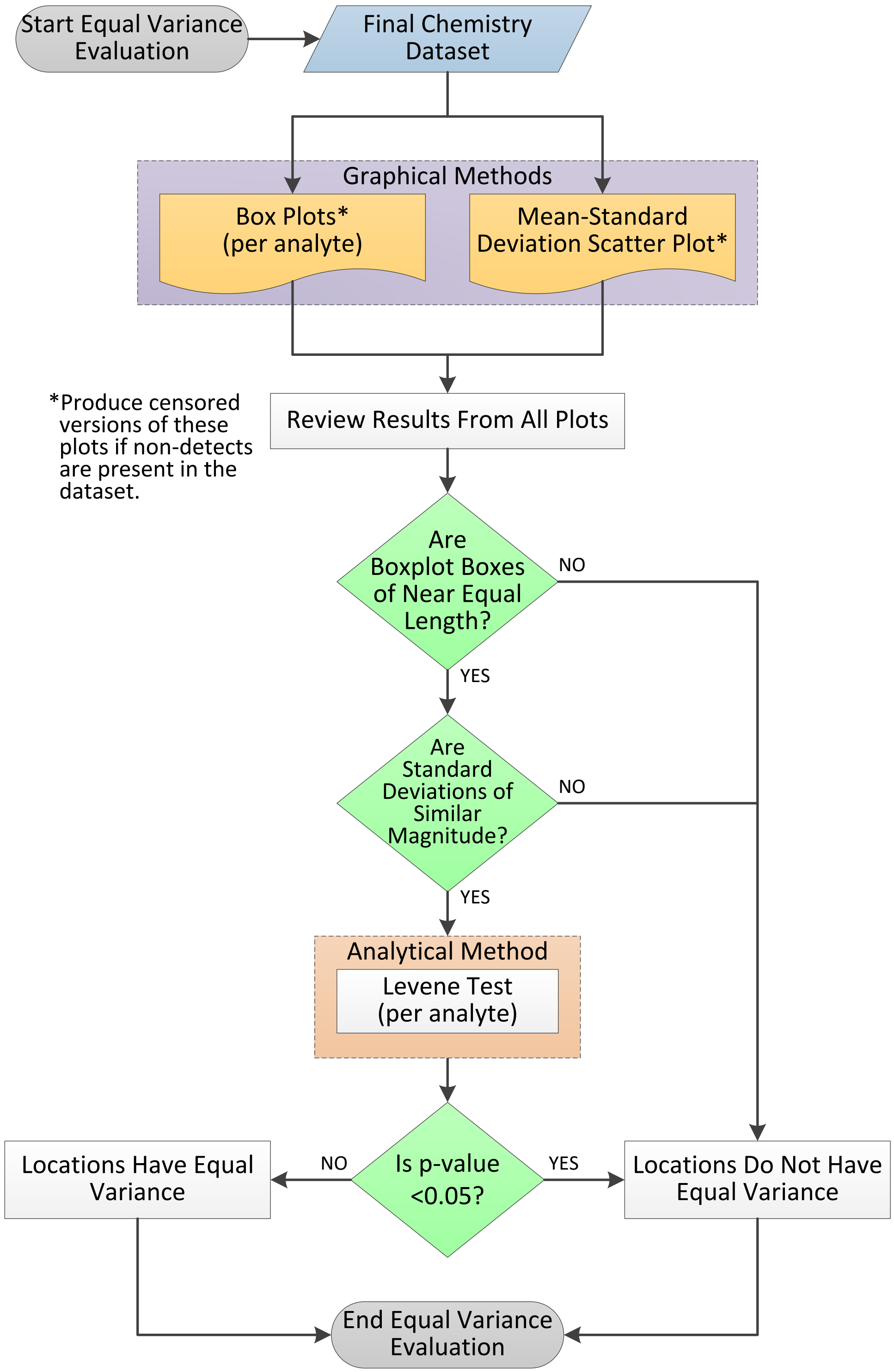

Figure E-7. Equal Variance Evaluation

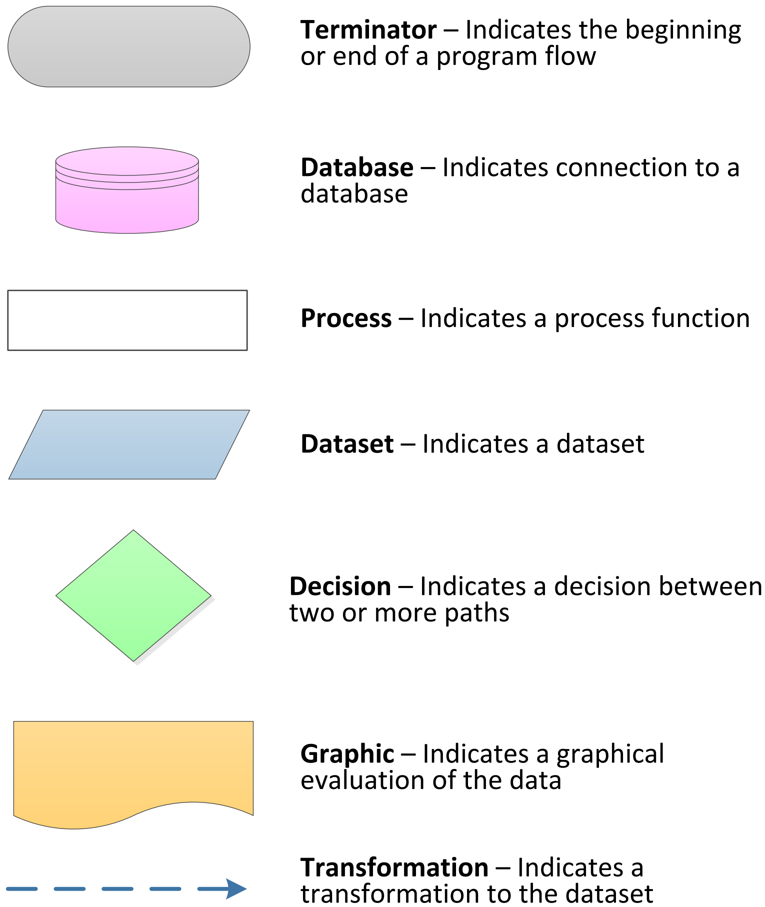

Figure E-8. Chart Legend

E2 References

Ecology Publication No. 97-407, 2014, *Chemical Test Methods For Designating Dangerous Waste WAC 173-303-090 & -100*, Hazardous Waste and Toxics Reduction Program, Washington State Department of Ecology, Olympia, Washington. Available at: https://fortress.wa.gov/ecy/publications/documents/97407.pdf.

EPA 530/R-09-007, 2009, *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities Unified Guidance*, Office of Resource Conservation and Recovery, U.S. Environmental Protection Agency, Washington, D.C. Available at: https://www.itrcweb.org/gsmc-1/Content/Resources/Unified_Guidance_2009.pdf.